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HIGH-SPEED RAILWAY, MARKET ACCESS, AND ECONOMIC GROWTH

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Abstract

This paper establishes a general equilibrium trade model and adopts the "market access" approach to measure the impact of the high-speed railway (HSR) network on the economic growth of 110 of the main prefecture-level cities of the People's Republic of China, for which we manually collect the pairwise travel distances and railway speeds to calculate the market access (MA). The empirical results show that the launch of the HSR exerts significant positive effects on growth; specifically, a 1% increase in MA leads to an increase in real income of 0.123% (controlling the region fixed effect) or 0.121% (controlling the province fixed effect). Counterfactual econometric analysis indicates that, if all the HSR were removed in 2015, the market access would fall by an average of 76.2% and the aggregate real income would decline by up to 9.4%. The growth effect of the HSR varies across cities, and the HSR has a more prominent impact on services than on manufacturing. The conclusion remains valid after a series of robustness tests.

Keywords: high-speed railway, transport infrastructure, market access, economic growth, PRC

JEL Classification: F14, R11, R42

Contents

1. INTRODUCTION

Many have long considered investment in the transport infrastructure to be one of the key factors in promoting economic growth (Fogel 1964; Donaldson 2010). The transport infrastructure has an impact on the economy through the direct effect of "investment goods" and the indirect effect of quasi-public goods (Li, Wang, and Yu 2011; Wang and Ni 2016). Infrastructure investment drives the development of interrelated industries through the multiplier effect, which has a direct stimulating influence on regional economic growth. The indirect effect is apparent in reducing transport costs and time costs, accelerating the integration of the market, facilitating the rapid flow of the labor force and factors, leading to the dissemination of knowledge and technology, and contributing to improving inter-regional technical efficiency and optimizing resource allocation. The investment-driven mode has played a prominent role in the fast economic growth in the People's Republic of China (PRC) over the past 30 years, while transport investment has accounted for a huge proportion of the total investment in fixed assets. The past decade has evidenced fast construction of the high-speed railway (HSR) in the PRC. Following the launch of the first HSR line in 2007, the mileage of the HSR reached 19,000 km by the end of 2015 and will double that amount to reach 38,000 km in 2025. By then, the HSR network will connect the big metropolitan cities and most prefecture-level cities intensively.[1]

The opening of the HSR has been the driving force behind the PRC's national economic growth. However, on the regional or city level, the HSR may present a positive spillover effect to stimulate convergence in growth or it may enlarge the income differences between big metropolitan cities and other cities through the siphon effect or the backwash effect. Many researchers have selected some HSR lines and set up DID or spatial econometric models to examine the specific effect on house prices, employment, factor flows, and the rural–urban income gap (Zhang 2012; Zhou and Zheng 2012; Zheng and Kahn 2013; Lin 2014; Lin, Qin, and Xie 2015; Qin 2016; Wang and Ni 2016; Zhang and Tao 2016). Most of these studies have examined the local effect of the HSR, yet very few studies have investigated globally the causal effects of the HSR or revealed the internal mechanism that drives the impact.

Donaldson (2010) originally used the events of historical infrastructure construction and found that the construction of railways improves the market environment and welfare level. Based on the Ricardo trade model of Eaton and Kortum (2002), Donaldson and Hornbeck (2016) proposed the market access approach to quantify the causal effect of the US railway on economic growth. Alder (2015) used the market access approach to examine the growth effects of an Indian highway project. The market access approach derives a reduced-form measure of the aggregate impact of infrastructure on growth. The market access for each city is obtained by summing its trading partners' income, discounted by bilateral trade costs and by the market access of destinations. It is possible to capture simultaneously the direct and indirect effects of the transport infrastructure in each city to measure the impact of changes in the transport infrastructure on economic growth dynamically and accurately.

This paper extends the market access approach to quantify the causal effects of HSR construction on the PRC's economic growth. Compared with the extant research on the density of local railways, the market access approach in this paper has the advantages that it exposes the fact that changes elsewhere in the railroad network can influence

[1] The data are from *The Mid–Long Term Railway Network Plan of China* issued by the National Committee of Development and Reform, version 2016.

any city's market access; it captures both direct and indirect effects of the transportation infrastructure and estimates the total treatment effect in an environment with nationwide spillover effects; and it provides a structured comprehensive explanation for the estimated equations. In our model, the development of the transport infrastructure determines the bilateral trade costs, which in turn will change the market access. Therefore, with the HSR connecting more and more cities, we can derive a market access matrix for each year. The model also predicts a log-linear relationship between market access and income, which provides useful guidance and a structured explanation for the empirical analysis.

In this paper, we manually collect data on 110 prefecture-level cities with HSR access from 2006 to 2015 and calculate the pairwise trade costs to obtain 110×110 matrices of market access indicators. We therefore estimate the relationship between the real income and the market access for each city, that is, the elasticity of income with respect to the market access. According to the model, the elasticity of income with respect to the market access is constant. Therefore, once we have estimated the elasticity, we can establish a "counterfactual" estimate to forecast the income changes in each region under various counterfactual transport networks, because the market access indicators capture the general equilibrium effect of the transport infrastructure. This allows us to analyze its aggregate effect and distribution effect quantitatively and gives a specific estimation of the causal effects of the HSR on economic growth.

This paper is the first to establish a market access matrix of 110 prefecture-level cities in the period 2006–2015, during which the PRC constructed the HSR quickly, extending the coverage of the PRC's cities. Our main findings are as follows. First, through the model, we obtain the log-linear relationship between income and market access, and the estimation displays an elasticity of 0.123 (controlling the region fixed effect) or 0.121 (controlling the province fixed effect); that is, for every 1% increase in market access, the real income increases by 0.123% or 0.121%. Second, by quantifying the aggregate effect of the HSR, we conclude that the counterfactual "removal" of all the HSR in 2015 would result in a 9.4% reduction (controlling the region fixed effect) or 9.2% (controlling the province fixed effect) in the real income. Thirdly, by estimating the distribution effect of the existing HSR network, we find out that the impacts of connecting to the HSR vary considerably in different regions. Finally, we examine the impact of the HSR on the secondary sector and services and find that the impact on services is stronger.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 constructs a general equilibrium trade model that measures the effect of the transportation infrastructure on the income effect. Section 4 provides the empirical strategy and data explanation. Section 5 analyzes the impact of the HSR empirically. Section 6 carries out the robustness checks. Section 7 concludes.

2. RELATED LITERATURE

Our paper is related to two streams of literature, one about transport and growth and the other about the market access approach. The relationship between transport infrastructure and economic growth has long been a hot topic in economics. Smith (1776) pointed out that the size of the market, which is a result of the transport infrastructure, such as roads and canals, determines labor allocation. In the 20th century, many economists argued that the transport infrastructure is the overhead capital in social development (Rosenstein-Rodan 1943; Nurkse 1953; Rostow 1960). Fogel (1964) initially used the social savings method to examine the impact of railways on the US agricultural sector and argued that the lack of railways would lead to an increase in transportation costs of rivers or canals and that subtle differences in freight costs would lead to some areas being more prosperous than others. This method is common in transportation improvement and other technological innovations, but it has many limitations in theory and application (Lebergott 1966; White 1976; Leunig 2010). Recently, some scholars have studied the economic effects of transport. Baum-Snow (2007) assessed the impact of expressway access on the urban population. Atack et al. (2010) used the difference-in-difference method to examine the effect of railways, suggesting that access to railways increases the urban population share but has no effect on the population density. Cervantes (2013) established a computable general equilibrium model and used county-level data and the visualization method to examine the impact of American railways on output in the 19th century, suggesting that the removal of railways in 1990 would result in a 9.6% decline in output.

The PRC's transport infrastructure construction has been growing fast and has attracted wide attention. Empirical research has shown that the railway network has significant positive causal effects on the GDP per capita in the PRC (Banerjee, Duo, and Qian 2012) or helps to reduce the urban–rural income gap (Liu, Zhou, and Xu 2013). Many studies have tested the spatial spillover effect of transport in reducing factor flow costs, promoting investment, or reducing market segmentation (Liu and Hu 2010; Zhang 2012; Zhang and Song 2013; Fan, Song, and Zhao 2017). In recent years, with the rapid development of the transportation infrastructure, the adjustment and optimization of the economic spatial pattern has supported the evolution from space distance to time distance, and the opening of the HSR has accelerated the process. Therefore, the HSR may exert multiple effects on labor mobility, technology transfer, industrial upgrading, and regional growth. Zheng and Kahn (2013) confirmed that the HSR can promote market integration and lead to a rise in house prices. Lin (2014) investigated how the HSR can affect specialization and increase urban employment. Lin, Qin, and Xie (2015) used the event of the HSR construction to identify the direct effect and spillover mechanism of technology transfer, finding that technology transfer leads to a significant increase in patents for HSR-related industries and a significant spillover effect on those industries that are related to the HSR indirectly. Qin (2016) argued that the HSR exacerbates the agglomeration of large cities, leading to lower average incomes of county-level towns along the railway lines. Most of these studies used the popular spatial econometrics or difference-in-difference methods to examine the effect of railways. However, there are still open questions, such as: what is the internal mechanism that drives this impact? How can we specify the direct and indirect effect through a general equilibrium framework? How can we explain the difference in effects across regions? This paper mainly aims to answer the above questions.

The market access approach, with its theoretical framework and empirical testing, has been gaining popularity. Redding and Sturm (2008) used the division of Germany after World War II and the reunification of East and West Germany after 1990 as a natural experiment to estimate the impact of market access changes on the population. Hanson (2005) studied the relationship between US county wages and market access changes from 1970 to 1990 and confirmed that the geographical agglomeration of economic activities is due to the connection of product markets between regions, which in turn is a result of economies of scale and transportation costs. Based on the Ricardo trade model, Donaldson (2010) collected archival data on Indian transport projects and used GIS spatial computing tools to study the impact of railway construction on the Indian market environment and welfare level. His investigation of trade costs and trade flows built up a systematic study of the general equilibrium effect of the railway network through "market access." Head and Mayer (2011) measured the national economic geography environment with market access and found that it largely determines the national per capita income level. Alder (2015) used the market access approach to examine the growth effect of an Indian highway project; the counterfactual scenario of India replicating the PRC's expressway construction showed that, if this were to happen, the underdeveloped regions in India would benefit hugely. Snow et al. (2016) examined the effect of the PRC's expressway on urban growth, suggesting that an increase in market access leads to higher output and plays an important role in export-oriented policies and the rise of metropolitan cities.

As with most studies on networks, challenges remain in the market access approach. One concerns how to estimate the total treatment effect in an environment with significant spillover effects, since railways have an influence on all regions through interlinked trade networks. If the impact of the railway is limited, the analysis unit may be able to aggregate (Miguel and Kremer 2004). However, as in many empirical settings, summation may make the results incredible. The other challenge is how to solve the endogeneity problem and specify the causal effects of the transport infrastructure. Chandra and Thompson (2000) and Michaels (2008) suggested the inconsequential units approach, that is, the removal of important nodes, to deal with the problem. They believed that the construction of US highways mainly aims to connect larger cities, and the area through which the highway passes is not predetermined.

This paper contributes to the literature on the infrastructure network effect and market access approach in the following ways. First, it extends the general equilibrium model of market access that Donaldson and Hornbeck (2016) proposed. In our model, each region interacts with the product and factor markets. The model implies that there is a log-linear relationship between real income and market access in prefecture-level cities; it captures the spillover effect as well as the total treatment effect. Second, with manually collected data on 110 prefecture-level cities, we establish a yearly market access matrix of the cities in 2006–2015 to provide a profound empirical study. We measure how the expansion of the HSR network affects the market access of each prefecture-level city and in turn results in differences in the growth effect; we examine the aggregate effect and distribution effect of the HSR in different regions; and we test whether the effect differs in the secondary and service sectors. Third, we cope with several challenges to identify the causal effects of the transport infrastructure on real income. As for the endogeneity problem, our strategy is to resort to the inconsequential units approach, that is, to remove important nodes (such as direct-controlled municipalities and provincial capital cities). Regarding the possibility that the income shock may be spatially correlated, our strategy is to fix the real income at the level of 2006 (the last year before the launch of the HSR) when calculating the market access. As for the problem of omitted variables, our strategy is to exploit the panel structure to identify the causal relationship.

3. THE MODEL

The market access of a location is the sum of the trading partner's income, discounted by the bilateral trade costs and by the market access of trading partners, which we can use to measure the level and change of the transport network. Donaldson and Hornbeck (2016) used this framework to estimate the impact of the US rail network on land value. This paper extends the classical Ricardo model to study the effect of the PRC's HSR expansion on regional and national economic growth.

3.1 A Ricardo Model of Trade

The economy consists of many trading areas (e.g., prefectures in the People's Republic of China [PRC]), of which the origin area of trade is represented by o and the destination by d. Each prefecture utilizes the Cobb–Douglas production technology to produce varieties of goods indexed by j using land (L), labor (H),[2] and mobile capital (K). The production function is:

$$x_o(j) = z_o(j)(L_o(j))^{\alpha}(H_o(j))^{\gamma}(K_o(j))^{1-\alpha-\gamma} \quad (1)$$

where $z_o(j)$ denotes exogenous productivity.[3] The production function implies that the marginal cost is:

$$MC_o(j) = \frac{q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}}{z_o(j)} \quad (2)$$

where q_o is the land rental rate, w_o is the wage rate, and r_o is the interest rate.

The trade cost between the original and the destination area is measured through the "iceberg cost" assumption; that is, to transport one unit of goods to the destination area d, it is necessary to transport $\tau_{od} > 1$ units of goods from the original area o, and the loss ($\tau_{od} - 1$) is the trade costs. This implies that, if the price of goods produced in area o and sold locally is $P_{oo}(j)$, the price in area d will be $P_{od}(j) = \tau_{od} P_{oo}(j)$.

We assume that the market is perfectly competitive, so the price of each product equals its marginal cost in equilibrium. We have:

$$P_{od}(j) = \tau_{od} MC_o(j) = \tau_{od} \frac{q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}}{z_o(j)} \quad (3)$$

$$z_o(j) = \tau_{od} \frac{q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma}}{P_{od}(j)} \quad (4)$$

Consumers will choose the cheapest goods in the tradable goods to maximize their utility, so the price distribution will be subject to the distribution of productivity. Eaton and Kortum (2002) concluded that the price index satisfies the following relationship[4]:

---

2 We assume that the labor force is immobile, which is different from the assumption in Donaldson and Hornbeck's (2016) study. Both scenarios of the model actually obtain a log-linear relationship between real income and market access. The difference is the predicted elasticity, but it does not affect the estimation.

3 Each area draws its productivity $z_o(j)$ from a Frechet distribution with CDF $F_o(z) = \Pr[Z_o \le z] = \exp(-T_o z^{-\theta})$, where $\theta > 1$ represents a comparative advantage and T_o is the absolute advantage.

4 Since the capital is completely mobile, the rental rate of capital is equal everywhere to $r_o = r$. We define the constant as $k_1 = \mu^{-\theta} r^{-(1-\alpha-\gamma)\theta}$, where $\mu = \left[\Gamma\left(\frac{\theta+1-\sigma}{\theta}\right)\right]^{\frac{1}{1-\sigma}}$ and Γ is the gamma function.

$$
\begin{aligned}
P_d^{-\theta} &= k_1 \sum_o [T_o(\tau_{od} q_o^{\alpha} w_o^{\gamma})^{-\theta}] \\
&= k_1 \sum_o [T_o(q_o^{\alpha} w_o^{\gamma})^{-\theta} \tau_{od}{}^{-\theta}] \equiv CMA_d
\end{aligned}
\tag{5}
$$

CMA_d is defined as consumer market access, which measures how conveniently consumers can obtain cheap goods in area d. When the production costs and trade costs are low in the supply area, the market access in the sale area is relatively high, and consumers have better access to cheap goods. Equation (5) indicates that there is a negative relationship between price and consumer market access.

3.2 Trade Flows and Gravity

Based on Eaton and Kortum (2002), the expenditure share of area d in the goods from area o is:

$$
\frac{X_{od}}{X_d} = \frac{T_o(q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma})^{-\theta} \tau_{od}{}^{-\theta}}{\sum_o T_o(q_o^{\alpha} w_o^{\gamma} r_o^{1-\alpha-\gamma})^{-\theta} \tau_{od}{}^{-\theta}}
\tag{6}
$$

We assume that the total expenditure for each region is equal to the total income ($X_d = Y_d$). Rearranging the above equation:

$$
X_{od} = T_o(q_o^{\alpha} w_o^{\gamma})^{-\theta} \times Y_d \times k_1 CMA_d{}^{-1} \tau_{od}{}^{-\theta}
\tag{7}
$$

This equation is a standard gravity equation that dramatically simplifies the general equilibrium problem of spatial competition, and it can fit well empirically with trade flow data from different backgrounds (Anderson and Van Wincoop 2003, 2004; Head and Mayer 2014). When the income of the destination and the productivity of the original area increase, the trade flow increases as a result. Meanwhile, if the production costs, trade costs, and consumer market access of the destination rise, the trade flow decreases accordingly, indicating a negative relationship. By adding up all the destination areas and assuming market clearing for all commodities, we can obtain the total income of the original area o:

$$
Y_o = \sum_d X_{od} = k_1 T_o(q_o^{\alpha} w_o^{\gamma})^{-\theta} \sum_d [CMA_d{}^{-1} \tau_{od}{}^{-\theta} Y_d]
\tag{8}
$$

Therefore, we can define the "firm market access" of area o as:

$$
FMA_o \equiv \sum_d \tau_{od}{}^{-\theta} CMA_d{}^{-1} Y_d
\tag{9}
$$

Firm market access FMA_o depends positively on destination income Y_d , while it is negatively related to consumer market access CMA_d , because higher consumer market access means more competition when exporting goods to area d.

Donaldson and Hornbeck (2016) argued that, in the case of symmetrical trade costs, $FMA_o = \rho CMA_o = MA_o$ must be satisfied, where $\rho > 0$. In addition, MA_o is called market access. Under these conditions, we have:

$$MA_o = \rho \sum_d \tau_{od}^{-\theta} MA_d^{-1} Y_d \tag{10}$$

This nonlinear equation can capture the general equilibrium effect of bilateral trade costs τ_{od}, because the decline in the trade costs of area d affects its market access and exerts an impact on the market access of area o. Thus, the income becomes:

$$Y_o = k_1 T_o (q_o^{\alpha} w_o^{\gamma})^{-\theta} MA_o \tag{11}$$

Equations (10) and (11) summarize how the trade costs of each region affect the income. In particular, equation (11) provides the relationship between income and market access, indicating that we can obtain the direct and indirect effects of the transport infrastructure by measuring the changes in market access. Equation (10) shows that trade costs affect income through the channel of market access. The framework illustrates that regions that are better connected (with lower trade costs) are more influential on each other and that the impact increases with the size of the market in each region. Meanwhile, based on this general equilibrium model, we can quantify the aggregate effect. In particular, the market access approach takes into account the decline in bilateral trade costs τ_{di} for any two trading partners (such as areas d and i), which can have an impact on the market access for area o. It is apparent from equation (10) that the decline in τ_{di} will lead to an increase in MA_d, which in turn leads to a decline in MA_o.

In this paper, we examine the effect of the HSR on the real income in different cities. We assume that the real income is Y_d^r, which satisfies $Y_d = Y_d^r \times P_d$. Then, equation (10) becomes:

$$MA_o = \rho^{\frac{1+\theta}{\theta}} \sum_d \tau_{od}^{-\theta} MA_d^{-\frac{1+\theta}{\theta}} Y_d^r \tag{12}$$

Given the real income Y_d^r, bilateral trade costs τ_{od}, and trade elasticity θ, the solution of this nonlinear equation system can provide the market access for each region. For the sake of convenience, we use the first-order approximation of equation (12) to compute MA[5]:

$$MA_o \approx \sum_d \tau_{od}^{-\theta} Y_d^r \tag{13}$$

We substitute the wage and land rent rate in equation (11) with the factor income, then we have:

$$Y_o^r = (k_2 T_o)^{\frac{1}{1+\theta\alpha+\theta\gamma}} \left(\frac{\alpha}{L_o}\right)^{\frac{-\theta}{1+\theta\alpha+\theta\gamma}} \left(\frac{\gamma}{H_o}\right)^{\frac{-\gamma\alpha}{1+\theta\alpha+\theta\gamma}} MA_o^{\frac{1+\theta(1+\alpha+\gamma)}{(1+\theta\alpha+\theta\gamma)\theta}} \tag{14}$$

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5 Donaldson and Hornbeck (2016) compared the numerical solution for MA with its first-order approximation and found similar effects. For the measure of market access of prefecture-level cities that have open high-speed railways, see the appendix. Because Y_o^r is included in equation (13), we work with $MA_o \approx \sum_{d \neq o} \tau_{od}^{-\theta} Y_d^r$ to avoid the endogeneity problem.

where $k_2 = k_1 \rho^{-\frac{1}{1+\theta\alpha+\theta\gamma}}$. Equation (11) indicates that the effect of the transportation network on real income is achieved through market access, and equation (14) further specifies that there is a log-linear relationship between real income and market access. In the following section, we will use the framework to measure the effect of the HSR on the real income in the PRC's cities and determine how the mechanism works.

4. EMPIRICAL STRATEGIES AND DATA

4.1 Empirical Strategies

Considering the unobservable heterogeneity across regions, we use the fixed-effect panel regression to estimate and identify causal relationships. Taking the logarithm on both sides of equation (14) and taking into account the varying time, we obtain:

$$\begin{aligned} \ln(Y_o^{\gamma}) = & \underbrace{-\frac{\theta\alpha}{1+\theta\alpha+\theta\gamma}\ln\left(\frac{\alpha}{L_o}\right) - \frac{\gamma a}{1+\theta\alpha+\theta\gamma}\ln\left(\frac{\gamma}{H_o}\right)}_{\text{Constant over time}} \\ & + \underbrace{\frac{1}{1+\theta\alpha+\theta\gamma}\ln(k_{2,t})}_{\text{Country characteristics}} + \underbrace{\frac{1}{1+\theta\alpha+\theta\gamma}\ln(T_{o,t})}_{\text{Productivity}} \\ & + \underbrace{\frac{1+\theta(1+\alpha+\gamma)}{(1+\theta\alpha+\theta\gamma)\theta}\ln(MA_{o,t})}_{\text{Market access}} \end{aligned} \tag{15}$$

The corresponding panel fixed-effect specification is:

$$\ln(Y_o^{\gamma}) = \phi_0 + \delta_{s,t} + \beta \ln(MA_{o,t}) + \varepsilon_{o,s,t} \tag{16}$$

where ϕ_0 denotes the fixed effect of each region and $\delta_{s,t}$ is the "region–year" fixed effect. The link between (15) and (16) is as follows. The first line on the right side of equation (15) consists of parameters and factor endowments, which we assume to be constant over time so that the regional fixed effect can absorb them. The second line includes the national characteristics (interest rate) and the productivity of each region. The "region–year" fixed effects absorb the changes in the interest rates, and the regional productivity may change over time and region. As will be discussed below, the identification strategy in this paper uses exogenous changes in infrastructure; thus, unobservable productivity changes have no impact on the transport infrastructure. Furthermore, the "region–year" fixed effect absorbs some unobservable changes. The last line on the right side of equation (15) represents the effect of market access.

There are several challenges involved in identifying the causal effects of the transport infrastructure on real income. First, the choice of infrastructure construction may not be exogenous. Especially, the fact that some HSR lines were built to connect more developed big cities in the early years makes people suspect that many areas may happen to be located on HSR lines just because they are the interconnection between big cities. To solve this problem, we follow the inconsequential units approach[6] and remove important nodes (such as direct-controlled municipalities and provincial capital cities) so that the HSR will affect the remaining areas exogenously.

The second challenge of the identification is that the income shock may be spatially correlated. Since the market access of area o is the sum of the income of its trading partners (i.e. area d), the change in market access may be related to the income of area o if a spatially correlated income shock affects the real income of area o and area d. In that case, it is possible to observe the relationship between real income and market access even if the transport infrastructure is not improved (the trade costs remain unchanged). To solve this problem, we use the real income of cities in 2006 when calculating the market access matrix to ensure that changes in market access result only from changes in the transport infrastructure (and thus the trade costs). Thus, we revise equation (12) as follows:

$$MA_o = \rho^{\frac{1+\theta}{\theta}} \sum_d \tau_{od}{}^{-\theta} MA_d{}^{-\frac{1+\theta}{\theta}} Y_{d,2006}^{\gamma} \quad (17)$$

$$MA_o = \rho^{\frac{1+\theta}{\theta}} \sum_d \tau_{od}{}^{-\theta} MA_d{}^{-\frac{1+\theta}{\theta}} Y_{d,2006}^{r}$$

Similar to equation (12), the first-order approximation is used to calculate the market access in this case. According to the model, the elasticity of income with respect to market access (β in (16)) is constant. Given an identification strategy to estimate β, it is also possible to calculate the income level in various "counterfactual" scenarios (which means different market access values).

4.2 Data

We manually collect data on 110 prefecture-level cities in 2006–2015, which include most of the cities that the HSR has covered since its launch in 2007. To examine the impact of the HSR opening on market access, we choose these 110 prefecture-level cities through which both the HSR and the ordinary railway passed during this period so that we can conveniently calculate the shortest travel time for ordinary railways and the HSR between any two of the cities, respectively. The data on the prefecture-level cities are from the provincial statistical yearbooks. The explained variables of the model are the real GDP (the nominal GDP divided by the GDP deflator[7]) of the prefecture-level cities, and then we take the logarithm.

To calculate the "market access," we need to define the bilateral transport costs with the method that Roberts et al. (2012) proposed. Due to the assumption of the economy of scale, that is, the transport costs increase less than the increase in distance (Au and Henderson 2006), we calculate the transportation cost between area o and area d as:

$$\tau_{od} = 1 + t_{od}^{0.6} \quad (18)$$

[6] Chandra and Thompson (2000), Michaels (2008), and so on proposed this identification strategy, and Banerjee, Duo, and Qian (2012), Asturias, Garcfa-Santana, and Ramos (2014), and Ghani, Goswami, and Kerr (2015) successfully applied it to infrastructure research in the PRC and India.

[7] The GDP deflator comes from the indicator of the World Bank: http://data.worldbank.org/indicator/NY.GDP.DEFL.ZS.

where τ_{od} is the transport cost between two regions and t is the shortest travel time between them. Then, we take the following steps to measure market access. First, we manually obtain the travel time across regions in 2006 when the HSR was absent, resulting in a 110×110 time matrix of ordinary railways with a diagonal of 0, in which each row vector represents a city's shortest travel time to 109 other cities by ordinary railways. Second, we check each of the 110 cities when it was connected to the HSR network during 2007 and 2015, replacing the travel times by ordinary railways with the shortest travel time by the HSR, resulting in a new transport time matrix for that year. Finally, the corresponding time matrix is transformed into a 110×110 transport cost matrix though equation (18). We substitute the resulting transport cost matrix and the real income for the corresponding year into equation (13) to obtain the MA (market access) over the years. The shortest travel time between two areas comes from the "China Railway Customer Service Center." The control variables include the region dummy variables, east, west, and central. We also consider the real GDP of the prefecture-level cities in 2001, the GDP growth rate of the provinces in 2001–2006, and the proportions of the secondary and the tertiary sectors in the GDP.[8] The construction of an HSR takes many years, and the year-to-year difference in HSR coverage is not huge; we choose the years 2007, 2010, and 2015 for the empirical study so that we can control the region–year fixed effect. Table 1 provides a statistical description of the major variables in these three years.

Table 1: Statistical Description of the Major Variables

Variable	Definition	N	Mean	Std Dev.	Min.	Max.
Lngdp	The log of real income	330	21.140	0.999	18.838	23.819
Lnma	The log of market access	330	13.203	1.470	9.725	17.040
lgdp01	The log of real income in 2001	330	20.202	0.886	18.281	22.711
growth	The GDP growth rate of each province from 2001 to 2006	330	0.161	0.022	0.123	0.199
Ind2	The proportion of the secondary industry in the GDP in 2001	330	0.452	0.061	0.307	0.561
Ind3	The proportion of the tertiary industry in the GDP in 2001	330	0.390	0.051	0.323	0.672

5. EMPIRICAL ANALYSIS

5.1 The Growth Effect of the HSR

The estimation of β in equation (16) represents the elasticity of real income with respect to market access, and Table 1 presents the results. Since the HSR construction takes a long time, the year-to-year changes are not discernable, so we examine the changes in the HSR network in 2006, 2010, and 2015, respectively. As a benchmark, the first column presents the fixed-effect model excluding any control variables. The estimated coefficient implies that a 1% increase in market access is associated with a 0.28% increase in real income.

[8] The Appendix contains a detailed description of the data and the process of measuring MA.

In the empirical analysis, we are more concerned about the causal effect of market access, but the existence of missing variables may produce endogeneity problems. In this regard, the empirical analysis of this part uses the panel data method to reduce the problems caused by missing variables. In particular, the fixed effects of the prefecture-level cities in column 1 of Table 1 can absorb factors that do not change over time but have an effect on the explained variables, such as the initial level of real income. Region–year fixed effects control the heterogeneity over time (such as differences in growth trends) at higher aggregate levels (e.g. eastern, central, and western). The addition of region–year fixed effects in column 2 of Table 1 shows that the estimated coefficient decreases from 0.28 to 0.14, with statistical significance of the same level.

Although column 2 absorbs the difference in growth rates for different regions between 2006 and 2015 and controls the potential differences in time trends, this approach may raise the problem that the differences in growth across regions may be related to changes in the transport infrastructure during the period; in other words, part of the effect of the transport infrastructure may be attributable to the "region–year" fixed effect rather than the increase in market access. This is quite likely, because the construction of the HSR may reduce the transport costs in some area more than others, leading to a higher economic growth rate in the former.

To solve this problem, we need to set up a "counterfactual" scenario to control the regional trend, which is independent of the transport infrastructure investment. We choose the economic growth rate of the provinces before 2006 to capture their growth trend before the opening of the HSR, and we add the level of real income in 2001 and the proportions of the secondary and the tertiary industry in the GDP in each province.[9] In Table 2, column 3 includes the interactions of the year with the initial real income in 2001 (lg01y10 and lg01y15), column 4 includes the interactions of the year with the growth of the province-level real income from 2001 to 2006 (Lgthy10 and Lgthy15), column 5 considers the interactions of the year with the proportion of the secondary and tertiary industries in the GDP in 2010 and 2015 (Ind2y10, Ind2y15, Ind3y10, and Ind3y15), and column 6 takes into account all the province-level control variables. When we replace the region–year fixed effects (column 2) with the province-level control variables (column 6), the estimated coefficient increases from 0.139 to 0.141. The coefficients and the statistical significance indicate that the results of the two methods to control the economic trend are similar.

One more challenge in identifying the causal effects of the HSR lies in the fact that the income shock may be spatially correlated. As we can see from equation (13), two channels have an impact on the initial market access MA_o: one is the bilateral trade costs τ_{od} , and the other is the destination real income Y_d^r . Equation (11) shows that a change in MA_o will lead to changes in the initial real income Y_o . There is a correlation between real income Y_o and market access MA_o if a spatially correlated income shock affects both (Y_o) and (Y_d^r). In this case, changes in trade costs do not necessarily cause the correlation between real income and market access. To solve this problem, we calculate market access holding income fixed at the level of 2006 (as shown in equation 17), thus ensuring that the market access change is only due to bilateral trade costs, which are in turn a result of changes in infrastructure. With the other conditions unchanged, we obtain the estimated results in Table 2. Compared with Table 1, all the coefficients are of the same sign and significance level. Table 2 shows that the launch of the HSR exhibits significant positive effects on growth; specifically, a 1% increase in MA leads to an increase in real income of 0.123% (controlling the region fixed effect) or 0.121% (controlling the province fixed effect). These coefficients are slightly lower than

[9] More precisely, we include the interactions of the year with these variables.

the corresponding ones in Table 1 (0.139 or 0.141, respectively), which is due to the fact that the calculation of market access in Table 3 uses the real income fixed in 2006 and excludes a possible spatial correlation of income shocks between regions. The estimations in Table 2 turn out to capture the effect of market access more accurately; therefore, we will report these as the main empirical result.

Table 2: Estimated Effect of Market Access on Real Income—Varying Income

	FE	Region	Province Control			
	lngdp	lngdp	lngdp	lngdp	lngdp	lngdp
lnma	0.281***	0.139***	0.148***	0.147***	0.156***	0.141***
	(25.87)	(4.50)	(4.50)	(5.20)	(4.99)	(4.07)
Ctrl*y10		0.333***				
		(10.06)				
Ctrl*y15		0.274**				
		(2.48)				
East*y10		0.225***				
		(5.80)				
East*y15		0.388***				
		(5.44)				
West*y10		0.407***				
		(11.97)				
West*y15		0.662***				
		(7.34)				
lg01y10			0.0138***			0.0245**
			(8.64)			(2.22)
lg01y15			0.0174***			0.0232
			(3.89)			(0.93)
Lgthy10				1.719***		0.462
				(10.13)		(0.60)
Lgthy15				2.216***		3.175***
				(4.70)		(2.68)
Ind2y10					–0.0402	–0.663**
					(–0.19)	(–2.47)
Ind2y15					0.00768	–1.121
					(0.02)	(–1.51)
Ind3y10					0.738***	0.0403
					(2.99)	(0.10)
Ind3y15					0.842*	–0.273
					(1.69)	(–0.60)
_cons	17.32***	19.03***	18.92***	18.94***	18.82***	19.00***
	(117.23)	(49.48)	(46.40)	(53.77)	(48.53)	(44.07)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	330	330	330	330	330	330
R2	0.6848	0.7820	0.7480	0.7518	0.7473	0.7613

Notes: The table shows the elasticity of real income with respect to market access (as equation 13 defines). All the regressions include city fixed effects. Column 1 just shows the regression of real income on market access, and column 2 includes additionally the region–year fixed effect. In columns 3, 4, and 5, we replace the region–year fixed effects respectively with a province-level control variable (interactions of the year with the initial real income in 2001, the growth of the province-level real income from 2001 to 2006, or the shares of the secondary and the tertiary industry). Column 6 includes all of the province-level control variables. The t-statistic values appear in the parentheses. *, **, and *** suggest significance at the 10%, 5%, and 1% level, respectively.

Table 3: Estimated Effect of Market Access on Real Income—Fixed Income in 2006

	FE	Region	Province Control			
	lngdp	lngdp	lngdp	lngdp	lngdp	lngdp
Lnma	0.356***	0.123***	0.126***	0.129***	0.134***	0.121***
	(24.65)	(4.12)	(3.99)	(4.61)	(4.38)	(3.66)
Ctrl*y10		0.407***				
		(17.93)				
Ctrl*y15		0.399***				
		(4.31)				
East*y06		–0.512***				
		(–10.43)				
East*y10		–0.220***				
		(–6.81)				
West*y06		–0.810***				
		(–11.52)				
West*y10		–0.332***				
		(–5.97)				
lg01y10			0.0176***			0.0301***
			(17.67)			(2.85)
lg01y15			0.0244***			0.0296
			(7.31)			(1.21)
Lgthy10				2.165***		0.238
				(18.46)		(0.32)
Lgthy15				3.037***		3.297***
				(8.36)		(2.77)
Ind2y10					0.0142	–0.692**
					(0.07)	(–2.62)
Ind2y15					0.155	–1.155
					(0.41)	(–1.55)
Ind3y10					0.879***	0.0631
					(3.54)	(0.17)
Ind3y15					1.046**	–0.275
					(2.13)	(–0.60)
_cons	16.45***	19.55***	19.19***	19.15***	19.09***	19.25***
	(86.36)	(49.23)	(48.99)	(54.84)	(50.20)	(46.87)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	330	330	330	330	330	330
R2	0.5637	0.7737	0.7364	0.7403	0.7341	0.7514

Notes: The table shows the elasticity of real income with respect to market access (as equation 17 defines). All the regressions include city fixed effects. Column 1 just shows the regression of real income on market access, and column 2 includes additionally the region–year fixed effect. In columns 3, 4, and 5, we replace the region–year fixed effects respectively with a province-level control variable (interactions of the year with the initial real income in 2001, the growth of the province-level real income from 2001 to 2006, or the shares of the secondary and the tertiary industry). Column 6 includes all of the province-level control variables. The t-statistic values appear in the parentheses. *, **, and *** suggest significance at the 10%, 5%, and 1% level, respectively.

Table 4: Estimated Effect of Market Access on Real Income—Deleting Capitals and Municipalities

	FE	Region	Province Control			
	lngdp	lngdp	lngdp	lngdp	lngdp	lngdp
Lnma	0.334***	0.133***	0.141***	0.130***	0.146***	0.134***
	(22.29)	(3.93)	(3.95)	(4.03)	(4.15)	(3.85)
Ctrl*y10		0.406***				
		(16.49)				
Ctrl*y15		0.329***				
		(3.14)				
East*y06		–0.493***				
		(–9.32)				
East*y10		–0.196***				
		(–5.18)				
West*y06		–0.733***				
		(–7.96)				
West*y10		–0.267***				
		(–4.02)				
lg01y10			0.0177***			0.0280**
			(17.17)			(2.02)
lg01y15			0.0217***			–0.0241
			(5.68)			(–0.66)
Lgthy10				2.171***		–0.241
				(17.56)		(–0.32)
Lgthy15				2.796***		5.250***
				(6.74)		(2.96)
Ind2y10					–0.277*	–0.826***
					(–1.67)	(–2.64)
Ind2y15					0.0146	–0.468
					(0.03)	(–0.48)
Ind3y10					1.236***	0.551
					(6.20)	(1.39)
Ind3y15					1.089	0.744
					(1.52)	(1.09)
_cons	16.45***	19.13***	18.74***	18.87***	18.67***	18.82***
	(82.96)	(42.40)	(42.18)	(46.56)	(42.67)	(43.28)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	261	261	261	261	261	261
R2	0.5047	0.7335	0.6891	0.6983	0.6940	0.7230

Notes: To identify the causal effect, we delete provincial capitals and municipalities. The table shows the elasticity of real income with respect to market access (as equation 17 defines). All the regressions include city fixed effects. Column 1 just shows the regression of real income on market access, and column 2 includes additionally the region–year fixed effect. In columns 3, 4, and 5, we replace the region–year fixed effects with a province-level control variable (interactions of the year with the initial real income in 2001, the growth of the province-level real income from 2001 to 2006, or the shares of the secondary and the tertiary industry). Column 6 includes all of the province-level control variables. The t-statistic values appear in the parentheses. *, **, and *** suggest significance at the 10%, 5%, and 1% level, respectively.

Another source of endogeneity is the reverse causality of economic performance on the transport infrastructure. As discussed in relation to the identification strategy in Section 4, the construction of the HSR may be not random, and its main purpose is to connect provincial capitals and mega-cities. Reasonably, the economic performance (or economic potential) of big cities is likely to drive the construction of the HSR. In other words, we need to identify whether the HSR is built to promote growth in less developed areas or to support growth in relatively advanced cities. Following the identification strategies that Chandra and Thompson (2000) and Michaels (2008) proposed, we exclude provincial cities and municipalities and consider that the HSR lines have a random effect on the remaining areas. Table 4 presents the corresponding regression results. In columns 2 and 6 of Table 4, the coefficients are 0.133 and 0.134, which are slightly higher than those in Table 3; however, all the coefficients in the first row are significant at the 1% level. The results show that, even if we exclude important node cities, the effect of market access on real income is still significantly strong, which also supports the idea that the endogenous selection of the HSR does not cause the relationship between market access and real income.

5.2 The Aggregate Effects of the HSR

To quantify the effect of the HSR on the overall economy, we build a "counterfactual" transport network with no HSR in 2015 and examine the extent to which the economic growth would change if there was no HSR. We calculate the market access matrix with the fixed real income of 2015 so that we can focus on the construction of the HSR as the only source of change. We compare two networks: the actual one is the HSR network operating in 2015, while the "counterfactual" one is the ordinary train network in 2006.

Through this calculation, we find that the market access would fall by an average of 76.2% if all the HSR was removed in 2015. However, the negative change in market access would differ across areas. Based on the regression results in Columns 2 and 6 of Table 2, we find that the removal of all the HSR in 2015 would result in an average decline in real income of 9.4% (controlling the region fixed effect) or 9.2% (controlling the province fixed effect). Given that the aggregate income of the 110 prefecture-level cities in 2015 was 43,745.02 billion yuan, [10] a 9.4% difference would roughly correspond to 4,112.03 billion yuan, which indicates the drastic differences resulting from the operation of the HSR. As a comparison, the result that we obtain through the counterfactual study is similar to the study on US railways. Donaldson and Hornbeck (2016) argued that the removal of all US railways would reduce market access by 80%, while Cervantes (2013), using the computable general equilibrium approach, showed that the removal of all US railways in 1990 would result in a 9.6% decline in output.

5.3 The Distribution Effects of the HSR

The real income level differs dramatically across cities, as does the HSR operation. How much does the opening of the HSR contribute to the regional differences? In addition to studying the aggregate effect of the HSR, we can further analyze the distribution effect by evaluating the effect of the HSR at local levels. Again, we establish a counterfactual scenario with no HSR in 2015 in each city and compare it with the actual situation. To discuss the differences across provinces or municipalities,

[10] According to the Statistical Yearbook of China, the total national income of 2015 was 68,263.51 billion yuan, and the total income of the 110 prefecture-level cities accounted for 64.1% of the total national income.

we base our analysis on the specification that controls the provincial growth trends (column 6 of Table 2) rather than controlling the "region–year" fixed effect (column 2 of Table 2).

Obviously, the operation of the HSR in 2015 led to faster economic growth compared with the counterfactual scenario without the HSR. However, the effect of the HSR differs across areas. The reason lies in the fact that the density and accessibility of the HSR differ across areas. For instance, the opening of the HSR in Fuzhou, Putian, Qingyuan, and adjacent areas increased their economic growth by more than 11%, implying that the economic growth in the region has benefited from the increased agglomeration effect of the HSR. However, some other areas may become losers due to trade diversion or siphon effects. For example, the HSR has no effect or even a negative effect on the economic growth in cities such as Chenzhou, Xianning, and Yangquan.

6. ROBUSTNESS TESTS

In this section, we conduct a series of robustness tests to strengthen the growth effect, aggregate effect, and distribution effect of the HSR in the PRC economy. First, we perform a robustness analysis with the trends in prefectures' growth prior to HSR investment. Second, we cope with abnormalities by weighting by the initial real income. Third, we choose alternative parameter values to verify the results. Finally, we study the impact of the HSR on the secondary and tertiary industries.

6.1 Trends in Prefectures' Growth prior to High-Speed Railway Investment

In section 5, we obtained a reliable causal effect of the HSR on regional growth through the identification strategy. However, there may be another concern that the construction of HSR lines is carefully selected in advance to pass through certain non-node cities. It is reasonably possible that the HSR runs mainly through the relatively fast-growing regions to promote regional cooperation further and optimize the allocation of resources; alternatively, the HSR may run through the lagging-behind regions to trigger economic development.

To solve this problem, we test whether the economic growth rate prior to the opening of the HSR is related to the decline in the transportation costs that the HSR caused. Thus, we use the growth rate between 2001 and 2005 as the explained variable and the market access changes from 2006 to 2015 as explanatory variables. If the HSR was precisely selected for those areas that were growing fast, then we should observe a positive correlation between the increases in market access due to the opening of HSR and the economic growth rate prior to its construction. On the contrary, if the HSR line was selected for those areas that initially developed slowly, a negative correlation would be observed. However, it is apparent from the estimation results in Table 5 that the estimated coefficients are insignificant in terms of both controlling the regional fixed effect and controlling the province fixed effect, and the absolute value of the estimated coefficients is quite small compared with any former estimation results. This provides compelling evidence against the hypothesis that the HSR may selectively connect certain non-node cities.

Table 5: Trends in Prefecture-Level Cities' Growth prior to HSR Investment

	Region Province Control					
	Growth	**Growth**	**Growth**	**Growth**	**Growth**	**Growth**
Incma	–0.00201	–0.00222	–0.00203	–0.00213	–0.00201	–0.00267
	(–0.65)	(–0.69)	(–0.65)	(–0.69)	(–0.66)	(–0.93)
Ctrl*y04		0.0393***				
		(4.61)				
Ctrl*y05		0.0130				
		(0.66)				
East*y02		0.0161				
		(1.52)				
East*y04		0.0381***				
		(3.64)				
East*y05		0.0314				
		(1.07)				
West*y02		0.0178				
		(0.49)				
West*y04		0.0316***				
		(2.92)				
West*y05		0.106***				
		(4.12)				
Ig01y04			0.00141***			–0.000989
			(4.74)			(–0.30)
Ig01y05			0.00105			–0.0259**
			(1.35)			(–2.18)
Lgthy04				0.224***		0.589**
				(6.11)		(2.58)
Lgthy05				0.211**		2.524***
				(2.22)		(5.65)
Ind2y04					0.202***	0.113
					(4.04)	(1.42)
Ind2y05					–0.146	–0.0600
					(–0.90)	(–0.25)
Ind3y04					–0.167***	–0.258**
					(–2.83)	(–2.29)
Ind3y05					0.229	0.403
					(1.08)	(1.04)
_cons	0.149***	0.125***	0.132***	0.127***	0.132***	0.141***
	(3.46)	(3.11)	(3.24)	(3.15)	(3.29)	(3.71)
N	261	261	261	261	261	261
R2	0.0104	0.0605	0.0284	0.0471	0.0485	0.1745

Notes: The table shows the results from regressing cities' income growth between 2001 and 2006 on changes in market access (as equation 17 defines) between 2007 and 2015. Column 1 just shows the regression of real income on market access, and column 2 includes additionally the region–year fixed effect. In columns 3, 4, and 5, we replace the region–year fixed effects respectively with a province-level control variable (interactions of the year with the initial real income in 2001, the growth of the province-level real income from 2001 to 2006, or the shares of the secondary and the tertiary industry). Column 6 includes all of the province-level control variables. The t-statistic values appear in the parentheses. *, **, and *** suggest significance at the 10%, 5%, and 1% level, respectively.

6.2 Weighting by the Initial Real Income

In the empirical analysis, the existence of extreme anomalies may mislead the results and reduce the credibility of the estimations. For example, some areas where the initial real income level is relatively low are likely to drive the results that we have obtained so far. Therefore, even a small change in the level of real income is likely to yield a large growth rate. To solve this problem, we use the logarithmic GDP in 2006 as weights to re-evaluate other variables to minimize the impact of abnormal values.[11] The regressions in Table 6 resemble those in Table 3 except that we weigh other variables by the logarithm of the initial real income in 2006. Comparing Table 6 and Table 3, we find that the regression coefficients are only slightly different and the significance level remains.

6.3 An Alternative Value for Trade Elasticity

The expression of market access in (13) requires the estimation of the trade elasticity θ. We select the initial value θ of 3.8 based on Donaldson (2010), who estimated trade elasticity with bilateral trade data during the colonial time. This estimated elasticity is consistent with the estimate that Simonovska and Waugh (2014) derived directly from current trade data. Eaton and Kortum (2002) examined a situation in which θ is equal to 12.86. However, different values of θ may have different impacts on the estimation of market access.

We focus on the case of $\theta = 1$ and $\theta = 7$, which is either greater or smaller than 3.8, to examine further whether the estimation is sensitive to the value of trade elasticity. With $\theta = 1$, the first-order approximation of market access in (13) looks like the expression of "market potential" in the new economic geography, which means the number and size of markets available at low trade costs (Harris 1954). The difference is that Harris (1954) simply used distance as a proxy variable for trade costs, but we measure trade costs and examine how the changes in the railway networks affect regional growth when the geographical distance remains fixed.

Comparing the estimation results in Tables 6, 7, and 8, it is evident that there is no obvious difference in the statistical significance of the regression coefficients, but the absolute values of the point estimates in Table 6 are smaller than those in Table 7 and larger than those in Table 8. This indicates that the estimates when the trade elasticity θ equals 3.8 are intermediate values compared with the estimates from the other alternative values.

[11] We weight the observations of real income and market access over the years by the log of real income in 2006.

Table 6: Estimated Effect of Market Access on Real Income—Weighting by the Initial Real Income

	FE	Region	Province Control			
	lngdp	Lngdp	lngdp	lngdp	lngdp	lngdp
lnma	0.354***	0.127***	0.133***	0.132***	0.138***	0.139***
	(24.24)	(4.08)	(4.00)	(4.67)	(4.47)	(3.81)
Ctrl*y10		0.0200***				
		(17.42)				
Ctrl*y15		0.0194***				
		(4.20)				
East*y06		–0.0238***				
		(–9.98)				
East*y10		–0.0101***				
		(–6.50)				
West*y06		–0.0392***				
		(–11.58)				
West*y10		–0.0159***				
		(–5.74)				
lg01y10			0.0178***			0.0587***
			(17.20)			(6.60)
lg01y15			0.0239***			0.0137
			(6.77)			(0.52)
Lgthy10				0.105***		–0.0121
				(18.06)		(–0.37)
Lgthy15				0.145***		0.178***
				(8.20)		(2.81)
Ind2y10					–0.00057	–0.0595***
					(–0.05)	(–4.55)
Ind2y15					0.00539	–0.0454
					(0.29)	(–1.29)
Ind3y10					0.0438***	–0.0288*
					(3.37)	(–1.95)
Ind3y15					0.0519**	0.00347
					(2.11)	(0.16)
_cons	0.792***	0.938***	0.920***	0.920***	0.917***	0.916***
	(85.35)	(47.17)	(46.39)	(54.02)	(49.61)	(41.95)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	330	330	330	330	330	330
R2	0.5544	0.7649	0.7264	0.7302	0.7243	0.7501

Notes: The table shows the elasticity of real income with respect to market access (as equation 17 defines). All the regressions include city fixed effects. Column 1 just shows the regression of real income on market access, and column 2 includes additionally the region–year fixed effect. In columns 3, 4, and 5, we replace the region–year fixed effects respectively with a province-level control variable (interactions of the year with the initial real income in 2001, the growth of the province-level real income from 2001 to 2006, or the shares of the secondary and the tertiary industry). Column 6 includes all of province-level control variables. We weight the observations by the log of prefecture-level cities' real income in 2001. The t-statistic values appear in the parentheses. *, **, and *** suggest significance at the 10%, 5%, and 1% level, respectively.

Table 7: Estimated Effect of Market Access on Real Income with Trade Elasticity (θ) of 1

	FE	Region	Province Control			
	GDP	GDP	GDP	GDP	GDP	GDP
lnma	2.234***	0.906***	0.767**	0.729***	0.822***	0.824***
	(16.26)	(3.26)	(2.62)	(2.71)	(3.11)	(2.87)
Ctrl*y10		0.0212***				
		(21.40)				
Ctrl*y15		0.0186***				
		(3.85)				
East*y06		–0.0229***				
		(–7.20)				
East*y10		–0.00802***				
		(–3.54)				
West*y06		–0.0420***				
		(–13.59)				
West*y10		–0.0181***				
		(–7.28)				
lg01y10			0.0194***			0.0591***
			(20.73)			(6.98)
lg01y15			0.0251***			0.0229
			(6.37)			(0.89)
Lgthy10				0.115***		–0.0265
				(19.88)		(–0.99)
Lgthy15				0.154***		0.174**
				(7.46)		(2.62)
Ind2y10					–0.00059	–0.0569***
					(–0.06)	(–4.62)
Ind2y15					0.00176	–0.0579*
					(0.09)	(–1.68)
Ind3y10					0.048***	–0.0225*
					(3.98)	(–1.69)
Ind3y15					0.0587**	–0.000768
					(2.26)	(–0.03)
_cons	–1.360***	0.0551	0.187	0.227	0.129	0.127
	(–9.30)	(0.19)	(0.60)	(0.79)	(0.46)	(0.42)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	330	330	330	330	330	330
R2	0.4893	0.7651	0.7168	0.7184	0.7144	0.7414

Notes: The table shows the elasticity of real income with respect to market access (as equation 17 defines with trade elasticity (θ) of 1). All the regressions include city fixed effects. Column 1 just shows the regression of real income on market access, and column 2 includes additionally the region–year fixed effect. In columns 3, 4, and 5, we replace the region–year fixed effects respectively with a province-level control variable (interactions of the year with the initial real income in 2001, the growth of the province-level real income from 2001 to 2006, or the shares of the secondary and the tertiary industry). Column 6 includes all of the province-level control variables. The t-statistic values appear in the parentheses. *, **, and *** suggest significance at the 10%, 5%, and 1% level, respectively.

Table 8: Estimated Effect of Market Access on Real Income with Trade Elasticity (θ) of 7

	FE	Region	Province Control			
	GDP	GDP	GDP	GDP	GDP	GDP
lnma	0.177***	0.0562***	0.0589***	0.0592***	0.0613***	0.0601***
	(17.77)	(3.87)	(3.69)	(4.37)	(4.03)	(3.47)
Ctrl*y10		0.0203***				
		(17.73)				
Ctrl*y15		0.0207***				
		(4.60)				
East*y06		–0.0251***				
		(–11.72)				
East*y10		–0.0112***				
		(–7.84)				
West*y06		–0.0407***				
		(–13.09)				
West*y10		–0.0173***				
		(–7.07)				
lg01y10			0.0181***			0.0569***
			(18.19)			(6.26)
lg01y15			0.0253***			0.0164
			(7.63)			(0.63)
Lgthy10				0.106***		–0.0147
				(18.85)		(–0.45)
Lgthy15				0.153***		0.175***
				(9.15)		(2.76)
Ind2y10					0.000471	–0.0558***
					(0.04)	(–4.41)
Ind2y15					0.00769	–0.0450
					(0.40)	(–1.26)
Ind3y10					0.0435***	–0.0263*
					(3.37)	(–1.80)
Ind3y15					0.0529**	0.00189
					(2.16)	(0.09)
_cons	0.975***	1.006***	0.989***	0.989***	0.989***	0.989***
	(403.34)	(278.40)	(359.50)	(408.74)	(369.03)	(334.72)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	330	330	330	330	330	330
R2	0.5276	0.7611	0.7221	0.7259	0.7195	0.7444

Notes: The table shows the elasticity of real income with respect to market access (as equation 17 defines with trade elasticity (θ) of 7). All the regressions include city fixed effects. Column 1 just shows the regression of real income on market access, and column 2 includes additionally the region–year fixed effect. In columns 3, 4, and 5, we replace the region–year fixed effects respectively with a province-level control variable (interactions of the year with the initial real income in 2001, the growth of the province-level real income from 2001 to 2006, or the shares of the secondary and the tertiary industry). Column 6 includes all of the province-level control variables. The t-statistic values appear in the parentheses. *, **, and *** suggest significance at the 10%, 5%, and 1% level, respectively.

6.4 The Impact of High-Speed Railway Opening on Different Sectors

We have discussed the effect of the HSR on growth through the channel of market access. Besides the aggregate effect, what is the impact of the HSR on the secondary and tertiary sectors?[12]

New economic geography believes that the economic agglomeration effects are mainly reflected in manufacturing and services. On the one hand, the operation of the HSR may exert an effect on the secondary sector by reinforcing the economy of scale in large cities or reducing the transport costs of goods by freeing up the freight capacity of highways and ordinary railways; on the other hand, the HSR has a direct effect on services, because the HSR operates mainly passenger transport and will promote the volume and speed of labor mobility. In Table 9, we show the effect of the HSR on the secondary sector. A 1% increase in MA leads to an increase in the secondary sector income of 0.116% (controlling the region fixed effect) or 0.103% (controlling the province fixed effect). Compared with those in Table 2, the estimated coefficients are still significant, while the absolute values of the regression coefficients are generally smaller, indicating a weaker effect on the secondary sector than on the overall economy. A possible reason is that most inputs and outputs of the secondary sector are transported by road and ordinary railways rather than by the HSR.

Table 10 shows the impact of the HSR on the tertiary sector. The absolute values of the regression coefficients are slightly larger than those in Table 2, indicating that the impact of the HSR on the tertiary sector is slightly greater than that on the overall economy. Besides, the regression coefficients are generally larger than those in Table 8, indicating that the tertiary sector is more sensitive to the opening of the HSR than the secondary sector, which is consistent with the fact that the high-speed railway is mainly for the passenger flow.

[12] According to the "Industry Classification of National Economy" (GB/T 4754-2011), the three sectors in the PRC are the following: the first sector refers to agriculture, forestry, animal husbandry, and fishery (excluding services in agriculture, forestry, animal husbandry and fishery); the second sector refers to mining (excluding mining auxiliary activities), manufacturing (excluding metal products, machinery, and the equipment repair industry), the electricity, heat, gas, and water production and supply industry, and the construction industry; the third sector, or the service sector, refers to the remaining sectors except the primary and the secondary sector.

Table 9: Estimated Effect of Market Access on the Secondary Sector

	FE	Region	Province Control			
	lnindy2	lnindy2	lnindy2	lnindy2	lnindy2	lnindy2
lnma	0.327***	0.116***	0.111***	0.123***	0.120***	0.103***
	(19.94)	(3.66)	(3.40)	(4.07)	(3.75)	(2.96)
Ctrl*y10		0.525***				
		(18.21)				
Ctrl*y15		0.473***				
		(5.20)				
East*y06		–0.369***				
		(–6.54)				
East*y10		–0.0944**				
		(–2.40)				
West*y06		–0.877***				
		(–10.24)				
West*y10		–0.302***				
		(–4.49)				
lg01y10			0.0204***			0.0477**
			(16.42)			(2.59)
lg01y15			0.0234***			0.0582**
			(7.09)			(1.99)
Lgthy10				2.444***		–1.169
				(14.89)		(–1.01)
Lgthy15				2.794***		1.143
				(7.29)		(0.78)
Ind2y10					–0.0531	–0.858*
					(–0.16)	(–1.90)
Ind2y15					–0.0155	–1.512**
					(–0.04)	(–2.25)
Ind3y10					1.095***	0.0704
					(2.67)	(0.11)
Ind3y15					1.184**	–0.495
					(2.25)	(–0.62)
_cons	16.10***	18.86***	18.66***	18.51***	18.55***	18.76***
	(74.41)	(44.85)	(45.93)	(48.86)	(46.28)	(43.24)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	330	330	330	330	330	330
R2	0.4724	0.7390	0.6780	0.6694	0.6766	0.6922

Notes: The table shows the elasticity of the secondary industry with respect to market access (as equation 17 defines). All the regressions include city fixed effects. Column 1 just shows the regression of real income on market access, and column 2 includes additionally the region–year fixed effect. In columns 3, 4, and 5, we replace the region–year fixed effects respectively with a province-level control variable (interactions of the year with the initial real income in 2001, the growth of the province-level real income from 2001 to 2006, or the shares of the secondary and the tertiary industry). Column 6 includes all of the province-level control variables. The t-statistic values appear in the parentheses. *, **, and *** suggest significance at the 10%, 5%, and 1% level, respectively.

Table 10: Estimated Effect of Market Access on the Tertiary Sector

	FE	Region	Province Control			
	lnindy3	lnindy3	lnindy3	lnindy3	lnindy3	lnindy3
lnma	0.441***	0.122***	0.131***	0.129***	0.140***	0.125***
	(25.96)	(4.39)	(4.50)	(5.08)	(5.05)	(4.22)
Ctrl*y10		0.338***				
		(13.94)				
Ctrl*y15		0.530***				
		(5.98)				
East*y06		–0.744***				
		(–14.55)				
East*y10		–0.379***				
		(–12.23)				
West*y06		–0.846***				
		(–13.19)				
West*y10		–0.421***				
		(–7.53)				
lg01y10			0.0175***			0.0178**
			(17.17)			(2.20)
lg01y15			0.0323***			0.0238
			(10.20)			(1.11)
Lgthy10				2.182***		0.972
				(19.93)		(1.50)
Lgthy15				4.091***		5.071***
				(12.33)		(3.68)
Ind2y10					0.158	–0.422*
					(0.95)	(–1.71)
Ind2y15					0.649	–0.890
					(1.43)	(–1.06)
Ind3y10					0.706***	0.0809
					(3.65)	(0.27)
Ind3y15					0.879	–0.597
					(1.65)	(–1.44)
_cons	14.36***	18.67***	18.12***	18.14***	18.01***	18.20***
	(63.95)	(50.40)	(50.22)	(57.20)	(52.33)	(49.70)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	330	330	330	330	330	330
R2	0.6341	0.8266	0.8112	0.8234	0.8067	0.8289

Notes: The table shows the elasticity of the tertiary industry with respect to market access (as equation 17 defines). All the regressions include city fixed effects. Column 1 just shows the regression of real income on market access, and column 2 includes additionally the region–year fixed effect. In columns 3, 4, and 5, we replace the region–year fixed effects respectively with a province-level control variable (interactions of the year with the initial real income in 2001, the growth of the province-level real income from 2001 to 2006, or the shares of the secondary and the tertiary industry). Column 6 includes all of the province-level control variables. The t-statistic values appear in the parentheses. *, **, and *** suggest significance at the 10%, 5%, and 1% level, respectively.

7. CONCLUSIONS

People often consider transport infrastructure investment to be the core means of promoting economic development, and the absence of transport infrastructure is one of the main constraints on development in many countries. As the impact of the construction of the transport network is global and has strong spillover effects, it is difficult to assess the impact of the transport infrastructure and its causal effect.

In this paper, we establish a general equilibrium trade model and adopt the "market access" approach to measure the impact of the high-speed railway (HSR) network on the economic growth of 110 of the main prefecture-level cities in the PRC, for which we manually collect the pairwise travel distances and railway speeds to calculate the market access (MA) of each city during the period 2006–2015. The empirical results show that the launch of the HSR exhibits significant positive effects on growth; specifically, a 1% increase in MA leads to an increase in real income of 0.123% (controlling the region fixed effect) or 0.121% (controlling the province fixed effect). The conclusion remains valid after a series of robustness tests. Through counterfactual econometric analysis, we find that, if all the HSR were removed in 2015, the market access would fall by an average of 76.2%, and the aggregate real income would decline by up to 9.4%. Furthermore, by establishing a counterfactual scenario with no HSR in 2015, we identify a significant distribution effect of the HSR in that the effect of the HSR differs drastically across areas. In most cities, the effect of the HSR on real income is significantly positive, while in several cities its effect is trivial or even negative.

A set of policy implications can be derived from our research. First, we should further speed up the construction of the HSR infrastructure. According to the empirical results of this paper, the opening of the HSR promotes economic growth at the national and regional levels. The investment in HSR will stimulate upstream and downstream industries and provide a driving force for growth through the investment multiplier effect.

Second, this paper finds that the growth effect of the HSR is significant at the national level, yet the effect is heterogeneous in different regions, which is due to the difference in the road network density and the accessibility of the HSR. The effect of the HSR on increasing market access and stimulating growth is relatively weak in inland areas and especially weak in western areas. Therefore, the future construction and operation of HSR should have different goals. In eastern areas, where the HSR is more densely located, there should be more focus on improving the HSR interconnections across regions. In inland areas, especially western areas, the country should construct more HSR lines to form an efficient HSR network.

Third, the efficient passenger flow through HSR can develop metropolitan cities. More and more mega-cities are facing the challenges of heavy population density, high traffic congestion, severe environment pollution, high housing prices, and insufficient public goods supply. The HSR network enables the development of more urban agglomerations, like the city belts, metropolitan cities, or city clusters that have been emerging in the Yangtze Delta, in the Pearl River Delta areas, or along the middle Yangtze River.

Finally, this paper illustrates that the impact of the HSR on different sectors is heterogeneous and that the impact on the service sector is more prominent. Services have already taken up more than 50% of the GDP and are playing an increasingly important role in growth. We should pay more attention to the coordination of different transport modes. We propose taking the HSR as the leading transport network and combining the ordinary railways, highways, waterways, and airlines to enhance the interconnection level of each region comprehensively. Only in this way can we reduce the transport costs and increase the market access to promote sustained economic growth.

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APPENDEXES

This section provides detailed information on the variables that we use in the text, including the sample selection, the main explanatory variables, other variable data sources, and processing.

A.1 SAMPLE SELECTION

In this paper, we study the effect of high-speed rail on economic growth. Specifically, we want to examine the economic impact on transport networks based on ordinary railways with the introduction of high-speed railways. Therefore, the research sample contains the prefecture-level cities where the ordinary railways and high-speed railways operated from 2006 to 2015, and the research methods used in this paper need to calculate the time matrices that are communicated with each other. To avoid inaccurate measurement of excessive transfer, we choose 110 prefecture-level cities as a research sample of cities that can reach each other by one or two transfers, which facilitates the calculation of the minimum operating time across the prefecture-level cities through the ordinary railway or the high-speed railway. Appendix Table 1 provides a description of the 110 prefecture-level cities, showing that the sample covers 23 provinces and cities, including 19 provinces and 4 municipalities.

Appendix Table 1: Description of 110 Prefecture-Level Cities

Provinces or Municipalities	The Selected Prefecture-Level Cities
Municipalities	Shanghai Beijing Tianjin Chongqing
Guangdong province	Guangzhou Dongguan Shenzhen Huizhou Zhaoqing Shaoguan Qingyuan
Jiangsu province	Nanjing Suzhou Wuxi Xuzhou Changzhou Zhenjiang
Hunan province	Changsha Hengyang Chenzhou Yueyang Huaihua Loudi Xiangtan Shaoyang Zhuzhou Yongzhou
Zhejiang province	Hangzhou Jiaxing Ningbo Jinhua Shaoshing Wenzhou
Shandong province	Jinan Qingdao Weifang Zibo Taian Zaozhuang Yantai Weihai Dezhou
Hubei province	Wuhan Xianning Xiaogan Yichang Tianmen Enshi
Hebei province	Sijiazhuang Baoding Cangzhou Langfang Xingtai Qinghuangdao Handan Tangshan
Henan province	Zhengzhou Xinyang Zhumadian Anyang Luohe Xinxiang Hebi Xuchang Sanmenxia Luoyang
Shanxi province	Taiyuan Linfen Yuncheng Yangquan
Liaoning province	Shenyang Dalian Liaoyang Tieling Huludao Anshan Yingkou Jinzhou Panjin
Anhui province	Hefei Bengbu Huainan Chuzhou Liuan Suzhou
Shaanxi province	Xian Xianyang Weinan Baoji
Jiangxi province	Nanchang Shangrao Yingtan Xinyu Pingxiang Yichun
Jilin province	Changchun Siping Jilin
Heilongjiang province	Haerbin
Sichuan province	Chengdu
Guizhou province	Guiyang
Guangxi province	Naming Liuzhou Hezhou Guilin Guigang Wuzhou
Fujian province	Fuzhou Putian Xiamen

A.2 THE MEASURE OF MARKET ACCESS

This paper uses the market access approach to measure the impact of the introduction of the high-speed railway on economic growth; the key to using this approach is the measure of market access. Equation (13) captures the market access of a location by summing the real income of trading partners, discounted by the bilateral trade costs. We can convert the measure of bilateral trade costs by the time of interconnection of each region through equation (18). Therefore, to obtain the market access of a location, we must first calculate the running time of the interconnection of 110 prefecture-level cities and then acquire the 110×110 time matrix.

On 18 April 2007, the sixth round of the "China railway speed up campaign" and the operation of the China Railway High-Speed (CRH) upgraded the speed of busy lines (Beijing–Shanghai (Jinghu), Longhai, Beijing–Wuhan (Jingguang), Jingha, Jiaoji, Guangshen, Shanghai–Changsha (Hukun)) to 200 or 250 km/h, marking the arrival of the first year of the PRC's high-speed railway. Appendix Table 2 shows the opening of high-speed rail lines in subsequent years.[13] This paper first constructs the time matrix of ordinary railways across regions in the absence of high-speed railways in 2006, resulting in a 110×110 time matrix of ordinary railways with a diagonal of 0, which means the running time of each place to itself, and each row vector represents a city's shortest travel time to 109 other cities though ordinary railways. Second, we find the prefecture-level cities that opened high-speed railways from 2007 to 2015, replacing their corresponding travel times by ordinary railways with the shortest travel time by the high-speed railway, resulting in a new transport time matrix for that year. Third, the corresponding time matrix is transformed into a 110×110 transport cost matrix though equation (18). The diagonal element of the cost matrix is 1, which means the cost of each place to itself, and each row vector represents a city's travel cost to 109 other cities though ordinary railways or high-speed railways.[14] Finally, we substitute the resulting transport cost matrix and the real income of the corresponding year into equation (13) to obtain the market access with changes in income over the years; Appendix Table 3 reports the basic statistical description of market access that varies with income. Furthermore, if we fix the real income to the level of 2006, we will obtain the market access for fixed income through equation (17); Appendix Table 4 reports the basic statistical description of market access for fixed income.

[13] We arrange the materials manually through the information of the Ministry of Railways' disclosure.

[14] If there are multiple routes between two regions, we choose the shortest time as the running time. If there is no direct route, we consider one or two transfers. For the calculation of convenience, we do not consider the site transfer time. The shortest travel time between two regions comes from the "China Railway Customer Service Center."

A.3 THE DATA SOURCES OF OTHER VARIABLES AND PROCESSING

The explained variable of the paper are the real GDP of prefecture-level cities, which is obtained though dividing the nominal GDP by the GDP deflator. The data on the prefecture-level cities are from the provincial statistical yearbooks, and the GDP deflator is from the World Bank Indicator.[15] The control variables include the variables of controlling the differences in the areas under study, which are the east, the west and the central variables, and these are all dummy variables. They also include the real GDP of the prefecture-level cities in 2001, the GDP growth rate of the provinces in 2001–2006, and the proportions of the secondary and the tertiary industry in the GDP.

Appendix Table 2: The Opening of HSR Lines from 2007 to 2015

Opening Date	Name	Start	End	Length (km)	Speed (km/h)
18/04/2007	Jinghu	Shanghai	Nanjing	301	200
18/04/2007	Longhai	Xi an	Baoji	173	200
18/04/2007	Jingguang	Beijing	Wuhan	1,199	200
18/04/2007	Jingha	Beijing	Haerbin	1,248	200
18/04/2007	Jiaoji	Jinan	Sifang	384	200
18/04/2007	Guangshen	Guangzhou	Shenzhen	147	200
18/04/2007	Hukun	Shanghai	Changsha	1207	200
18/04/2007	Hening	Hefei	Nanjing	166	200
01/08/2008	Beijing–Tianjin Intercity Railway	Beijing	Tianjin	113.5	350
21/12/2008	Jiaoji	Jiaozhou	Jinan	362.5	200
01/04/2009	Shitai	Shijiazhuang	Taiyuan	225	200
01/04/2009	Hewu	Hefei	Wuhan	359.4	250
28/09/2009	Yongtaiwen	Ningbo	Wenzhou	275	250
28/09/2009	Wenfu	Wenzhou	Fuzhou	298.4	250
26/12/2009	Wuguang	Wuhan	Guangzhou	1,068.8	350
28/12/2009	Zhengxi	Zhengzhou	Xian	505	350
26/04/2010	Fuxia	Fuzhou	Xiamen	226	250
13/05/2010	Chengguan	Chengdu	Dujiangyan	68	200
01/07/2010	Huning	Shanghai	Nanjing	301	350
20/09/2010	Changjiu	Nanchang	Jiujiang	131.3	250
26/10/2010	Hukun	Shanghai	Hangzhou	169	350
30/12/2010	Changji	Changchun	Jilin	112.5	250
30/12/2010	Hainan East Ring	Haikou	Sanya	308.1	250
30/06/2011	Jinghu	Beijing	Shanghai	1,318	380
26/12/2011	Guangshen	Guangzhou	Shenzhen	116	350
01/07/2012	Longxia	Longyan	Xiamen	171	200
01/07/2012	Hanyi	Wuhan	Yichang	291.8	200
16/10/2012	Hebeng	Hefei	Bengbu	130.7	300
28/09/2012	Shiwu	Zhengzhou	Wuhan	482.7	350
01/12/2012	Hada	Haerbin	Dalian	921	350

continued on next page

[15] The GDP deflator comes from the indicator of the World Bank: http://data.worldbank.org/indicator/NY.GDP.DEFL.ZS

Appendix Table 2 *continued*

Opening Date	Name	Start	End	Length (km)	Speed (km/h)
26/12/2012	Shiwu	Shijiazhuang	Zhengzhou	358	350
26/12/2012	Jingshi	Beijing	Shijiazhuang	281	350
30/12/2012	Suiyu	Suining	Chongqing	131	200
31/12/2012	Guangzhu	Guangzhou	Zhuhai	177.3	200
01/07/2013	Hangyong	Hangzhou	Ningbo	149.8	350
01/07/2013	Ninghang	Nanjing	Hangzhou	256	350
11/09/2013	Panying	Panjin	Yingkou	89.3	350
26/09/2013	Changfu	Nanchang	Fuzhou	632.4	200
01/12/2013	Jinqin	Tianjin	Qinhuangdao	261.3	350
28/12/2013	Xiashen	Xiamen	Shenzhen	514	250
28/12/2013	Yuli	Chongqing	Lichuan	264.4	200
28/12/2013	Wuxian	Wuhan	Xianning	91	250
28/12/2013	Maozhan	Maoming	Zhanjiang	103	200
28/12/2013	Xibao	Xian	Baoji	120.2	250
28/12/2013	Hengliu	Hengyang	Liuzhou	1,013	200
30/12/2013	Guangxi	Nanning	Beihai	262	250
30/12/2013	Liunan	Liuzhou	Nanning	226	250
18/06/2014	Wugang	Wuhan	Huanggang	36	250
18/06/2014	Wushi	Wuhan	Huangshi	97	250
01/07/2014	Yiwan	Yichang	Wanzhou	377	200
01/07/2014	Daxi	Taiyuan	Xian	567	250
16/09/2014	Hukun	Hangzhou	Changsha	927	350
26/12/2014	Hukun	Changsha	Xinhuang	420	350
20/12/2014	Chengmianle	Mianyang	Leshan	318	250
26/12/2014	Lanxin	Lanzhou	Wulumuqi	1,776	250
26/12/2014	Guiguang	Guiyang	Guangzhou	857	300
26/12/2014	Nanguang	Nanning	Guangzhou	577.1	250
01/01/2015	Lanyu	Chongqing	Weituo	70.7	200
18/06/2015	Hukun	Xinhuang	Guiyang	286	350
26/06/2015	Zhengjiao	Zhengzhou	Jiaozuo	78	250
28/06/2015	Hefu	Hefei	Fuzhou	852	300
17/08/2015	Haqi	Haerbin	Qiqihar	282	250
01/09/2015	ShenDan	Shenyang	Dandong	208	250
20/09/2015	Jituhun	Jilin	Hunchun	359	250
20/09/2015	Jingjinji	Tianjin	Yujiabao	44.8	350
21/09/2015	Guiguang	Guiyang	Longli	53.4	250
06/12/2015	Ningan	Nanjing	Anqing	257	250
10/12/2015	Musui	Mudanjiang	Muling	65	200
11/12/2015	Nankun	Nanning	Baise	224	250
17/12/2015	Danda	Dandong	Dalian	292	200
26/12/2015	Chengyu	Chengdu	Chongqing	308	350
26/12/2015	Lanyu	Guangyuan	Chongqing	352	200
26/12/2015	Ganlong	Ganzhou	Longyan	272.8	200
26/12/2015	Xinjinli	Jinhua	Wenzhou	188.8	200
28/12/2015	Jinbao	Tianjin	Baoding	157.8	250
28/12/2015	Musui	Muling	Suifenhe	74	200
30/12/2015	Hainan	Haikou	Sanya	345	200

Notes: The materials arrange manually though the information of the Ministry of Railways disclosure.

Appendix Table 3: Market Access with Income Changes

Variable		N	Mean	Std Dev.	Min.	Max.
lnma		330	13.603	1.607	9.725	17.666
lnma	2006	110	12.567	1.216	9.725	15.448
By year	2010	110	13.562	1.504	10.193	17.436
	2015	110	14.680	1.341	11.114	17.666
lnma	East	153	14.163	1.624	10.191	17.666
By region	Central	141	13.355	1.286	10.512	16.119
	West	36	12.193	1.590	9.725	15.843
lnma	Anhui	18	13.795	1.160	12.172	16.119
By province	Beijing	3	14.626	1.247	13.242	15.663
	Chongqing	3	11.592	1.103	10.717	12.831
	Fujian	9	12.630	1.641	10.191	14.806
	Guangdong	21	14.502	1.318	12.179	17.094
	Guangxi	18	11.777	1.138	10.456	13.723
	Guizhou	3	10.691	1.290	9.725	12.156
	Hebei	24	14.581	1.142	12.763	16.991
	Heilongjiang	3	12.568	1.222	11.176	13.467
	Henan	30	14.049	1.120	11.776	15.844
	Hubei	18	13.107	1.146	11.385	15.394
	Hunan	30	12.970	1.371	10.512	15.416
	Jiangsu	18	15.756	1.487	12.884	17.666
	Jiangxi	18	13.185	1.198	11.663	15.086
	Jilin	9	13.524	1.214	11.475	15.006
	Liaoning	27	13.806	1.310	10.814	16.157
	Shandong	27	13.224	1.552	10.391	15.791
	Shanghai	3	15.363	1.197	14.021	16.317
	Shanxi	12	12.419	1.151	10.780	14.118
	Shaanxi	12	13.976	1.414	11.461	15.843
	Sichuan	3	11.616	1.278	10.617	13.056
	Tianjin	3	15.124	1.291	13.675	16.153
	Zhejiang	18	13.894	1.730	10.367	16.400

Notes: According to the division of the eastern, central, and western parts of the National Bureau of Statistics of the People's Republic of China, the eastern part of the paper includes Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Shandong, Liaoning, Hebei, Tianjin, and Beijing; the central area includes Henan, Hubei, Hunan, Jiangxi, Shanxi, Anhui, Heilongjiang, and Jilin; and the western area includes Shaanxi, Sichuan, Chongqing, Guizhou, and Guangxi.

Appendix Table 4: Market Access with Income Fixed

Variable		N	Mean	Std Dev.	Min.	Max.
lnma		330	13.203	1.470	9.725	17.040
lnma	2006	110	12.567	1.216	9.725	15.448
By year	2010	110	13.122	1.515	9.725	16.920
	2015	110	13.921	1.349	10.391	17.040
lnma	East	153	13.792	1.483	10.191	17.040
By region	Central	141	12.941	1.101	10.512	15.283
	West	36	11.728	1.374	9.725	14.812
lnma	Anhui	18	13.376	0.972	12.172	15.283
By province	Beijing	3	14.184	0.831	13.242	14.813
	Chongqing	3	11.113	0.650	10.717	11.863
	Fujian	9	12.206	1.339	10.191	13.966
	Guangdong	21	14.137	1.113	12.179	16.347
	Guangxi	18	11.352	0.851	10.456	12.932
	Guizhou	3	10.278	0.957	9.725	11.383
	Hebei	24	14.192	0.906	12.763	16.161
	Heilongjiang	3	12.158	0.851	11.176	12.696
	Henan	30	13.641	0.841	11.776	15.108
	Hubei	18	12.623	0.931	11.385	14.462
	Hunan	30	12.600	1.249	10.512	14.740
	Jiangsu	18	15.392	1.322	12.884	17.040
	Jiangxi	18	12.762	0.933	11.663	14.286
	Jilin	9	13.120	0.940	11.475	14.263
	Liaoning	27	13.449	1.163	10.814	15.579
	Shandong	27	12.850	1.426	10.391	15.064
	Shanghai	3	14.987	0.846	14.021	15.593
	Shanxi	12	12.035	1.014	10.780	13.461
	Shaanxi	12	13.446	1.161	11.461	14.812
	Sichuan	3	11.059	0.765	10.617	11.942
	Tianjin	3	14.759	0.950	13.675	15.441
	Zhejiang	18	13.554	1.597	10.367	15.780

Notes: According to the division of the eastern, central, and western parts of the National Bureau of Statistics of the People's Republic of China, the eastern part of the paper includes Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Shandong, Liaoning, Hebei, Tianjin, and Beijing; the central area includes Henan, Hubei, Hunan, Jiangxi, Shanxi, Anhui, Heilongjiang, and Jilin; and the western area includes Shaanxi, Sichuan, Chongqing, Guizhou, and Guangxi.