Upgrade of Transportation Infrastructure and Siting of Polluting Enterprises:
The Case of High-Speed Railway Launch in China

Cai Hongbo (蔡宏波)[1], Zhong Chao (钟 超)[1,2*] and Han Jinrong (韩金镕)[1]
[1] *Business School, Beijing Normal University, Beijing, China*
[2] *Institute of European Studies, Chinese Academy of Social Sciences, Beijing, China*

Abstract: *With the quasi-natural experiment of the launching of high-speed railways in Chinese cities, this paper empirically investigated the effects of the upgrade of the transportation infrastructure on the site selection of polluting enterprises. We found that although the launching of a high-speed railway generally has a negative impact on the siting of polluting enterprises: (i) While there was a significant decrease in polluting enterprises of a private and other nature, the reduction in overseas-funded and state-owned enterprises was insignificant; (ii) while the launching of a high-speed railway greatly restrained the entry of polluting enterprises in the eastern region, large cities and more developed cities, this was followed by the movement of more polluting enterprises to the central and western regions, small and medium-sized cities and less developed cities; (iii) there was a significant decrease in polluting enterprises in environmentally conscious cities after the launching of a high-speed railway. This paper also found that infrastructure upgrade may influence the siting of polluting enterprises through the following: Environmental cleanness, factor concentration and spatial integration. Government authorities and market entities should be fully aware of and attach great importance to how the transportation infrastructure influences the site selection of businesses, as this is of great significance for China's regional development planning, local business climate and investment planning, environmental protection, and other related policymaking initiatives.*

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I. Introduction

When the People's Republic of China was founded in 1949, China's transportation infrastructure was very underdeveloped. At that time, the total length of the railway was only 21,800 km, half of which was in disrepair. Much has changed in China since that time. With the launch in 2003 of China's first dedicated passenger railway line, the Qinhuangdao-Shenyang Railway, China proceeded to build the

* CONTACT: Zhong Chao: e-mail: v_zhongchao@163.com.

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world's most technologically advanced, most integrated, longest, fastest and largest high-speed railway network. According to the *Sustainable Development of Transportation in China*, by the end of 2019, the total length of operating railway in China exceeded 139,000 km, among which 35,000 km was high-speed railway, ranking first in the world. Over the past decade, amid rapid urbanization, China's high-speed railway system has experienced rapid development and industrial upgrade. In September 2019, *Outline for Building a Leading Transportation Nation*, issued by the CPC Central Committee and the State Council, identified transportation as a leading sector for China's economic modernization. The Fifth Plenum of the 19th CPC Central Committee called for coordinated infrastructure development and upgrade of China's transportation system.

Having entered a new stage of development, China is implementing new development concepts and creating a new development paradigm with domestic circulation as the foundation and domestic and international circulations reinforcing each other. Transportation infrastructure is of great importance for unleashing domestic demand potentials, expanding investment, and coordinating urban and rural development. As the bloodline of the economy, the high-speed railway plays an increasingly important role in promoting regional growth and improving productive forces distribution as for strategic guiding and resources allocation. Yet the question is how does the transportation infrastructure influence the ecological environment and sustainable economic development while promoting industrial restructuring and spatial adjustment? This paper is concerned with how the upgrade of China's transportation infrastructure influences both the ecological environment and firm behavior. Another focus of our research is the potential mechanism by which the launching of a high-speed railway affects the siting of polluting enterprises as key market entities.

Based on relevant data on China's industrial enterprises and the *China City Statistical Yearbook*, this paper examines the effects of the launching of a high-speed railway on the siting of polluting enterprises. Over the period 2003-2013, fewer polluting enterprises were established in cities after the launching of a high-speed railway, down 33.01%, from 52.98 to 35.49, on an annual average basis. Although they offered the advantage of access to a high-speed railway, those cities did not welcome polluting enterprises. In this way, the effect of the launching of a high-speed railway varied across regions rather than being uniform. Whether polluting enterprises chose to locate in a city depended both on the city's location and on its environmental policy. In China's eastern region, for instance, an annual average of 57.26 polluting enterprises were opened in cities without access to a high-speed railway; this number stood at 43.35, or 22.55% less, for cities with access to a high-speed railway. In most cases, the presence of a high-speed railway did make better the already favorable location of prosperous cities. Moreover, cities in prosperous regions are more selective to incoming enterprises, and polluting enterprises lose their competitiveness.

Prosperous regions set higher environmental thresholds. As noted in the *Opinions of the CPC Central Committee and the State Council on Strengthening the Protection of the Ecological Environment in All Aspects and Firmly Winning the Battle of Preventing and Controlling Environmental Pollution* released in 2018, China has launched an all-round campaign for the closure, resettlement and improvement of poorly managed and polluting enterprises, focusing on key regions like the Beijing-Tianjin-Hebei Region and the Yangtze River Delta, making it less likely polluting enterprises will move in. The reverse is true for less developed central and western regions, where an annual average of 22.23 polluting enterprises were opened in cities with access to a high-speed railway, and the figure was 14.26 for those without access to a high-speed railway, or 55.89% fewer polluting enterprises. China's western regions are less attractive to investment due to distance to market, business climate and transportation infrastructure. As such, access to a high-speed railway gives cities in the central and western regions a much-needed offset. At the same time, under cost pressures and tightening environmental regulation some heavily polluting enterprises have been forced to relocate to the central and western regions. In contrast to the stringent environmental policy in the eastern region, the central and western regions have policies that attract polluting enterprises to move there, where they contribute to local economic development. Transportation infrastructure upgrade compensates for the unfavorable location of the central and western regions, making them more attractive destinations for polluting enterprises.

The launching of high-speed railways has greatly shortened the spatial-temporal distance between cities and facilitated the flow of labor, capital and other factors of production essential for economic growth, which may attract polluting enterprises. Access to a high-speed railway also helps improve regional economic conditions and household incomes, and high-income households demand better environmental quality, raising the threshold for polluting enterprises. In any case, an upgrade of the transportation infrastructure inevitably influences the spatial distribution of polluting enterprises.

In the context of green development, it is of great importance for the government to keep track of the movement of polluting enterprises. The question is how will the high-speed railway as a key transportation infrastructure influence the regional layout of polluting enterprises in China? What is the core mechanism? Which problems warrant attention? These are the key questions explored in this paper. This study on the effects of a high-speed railway on the siting of polluting enterprises builds upon previous research on the relationship between high-speed railways and regional economic growth, finance and land, i.e. "high-speed railway economics," with marginal contributions as follows:

(1) This paper investigates the effects at the city level of the launching of a high-speed railway on the siting of polluting enterprises, thus enriching research on how the upgrade of the transportation infrastructure influences the siting decisions of businesses. Most studies on business siting are focused on foreign-funded enterprises (Coughlin and Segev, 2000; Guimaraes *et al*., 2000) or general enterprises (Liu and Zhao, 2010). There has been a paucity of research on how the site selection of polluting enterprises in particular is influenced by upgrade of the transportation infrastructure. Based on previous research, this paper examines the dynamics of the establishment and development of polluting enterprises.

(2) Most previous studies analyzed the site selection of enterprises from such angles as the clustering effect of the transportation infrastructure (Li *et al*., 2016), accessibility (Chandra and Thompson, 2000), and industrial development (Faber, 2014). Few studies have considered the environmental threshold effect and the cleanup effect of the upgrade of the transportation infrastructure, which are vital to the site selection of polluting enterprises. By examining the clean development effects, this paper has enriched the current research and offers a reference for further learning about how the environmental effects of the upgrade of the transportation infrastructure may influence the siting of polluting enterprises.

(3) This paper contributes a unique research perspective on the site selection of enterprises. Most studies have only analyzed the spatial economic effects of the transportation infrastructure from the perspective of cities (Kim and Sultana, 2015). Few researchers have analyzed changes in the spatial layout of polluting enterprises in the context of the upgrade of the transportation infrastructure from the perspective of spatial relocation. This paper offers an empirical analysis of the motivations of polluting enterprises to relocate and the formation of the new spatial pattern, which helps make sense of the investment behaviors and dynamic layout of polluting enterprises.

The remainder of this paper is structured as follows: Section 2 reviews the historical reality of and relevant research on the relationship between transportation infrastructure and the site selection of enterprises. Section 3 creates a theoretical model to analyze the effects of a high-speed railway on the siting of polluting enterprises. Section 4 creates an econometric model and explains data sources. Section 5 performs an analysis based on the model's regression and test results. Section 6 verifies the above-mentioned mechanism of influence. Section 7 offers concluding remarks and policy recommendations.

2. Literature Review

2.1 Economic Effects of the Transportation Infrastructure

Cities emerge and thrive as a result of access to transportation (Hu and Liu, 2009; Zhang, 2012; Wang and Ni, 2016). Sasaki *et al*. (1997) found that Japan's Shinkansen significantly increased population and economic growth rates. Many studies consider that the transportation infrastructure has made cities more accessible and prosperous. For instance, Mejia-Dorantes *et al*. (2012) found a correlation between economic activity and the accessibility of cities, in which transportation infrastructure played a pivotal role. According to Chen and Haynes (2017), the high-speed railway facilitated regional economic integration and narrowed regional economic gaps. Most studies found the transportation infrastructure to be conducive to regional economic development. Based on a study on interstate highways in the US, Chandra and Thompson (2000) found that the transportation infrastructure would enhance the regional clustering effect and promote the regional economy along the route. Based on a study on the transportation infrastructure and regional economic growth in East Africa and the Indian Ocean Region, Njoh (2012) believed that more transportation infrastructure investment would induce regional economic growth.

From a microscopic point of view, most studies believed that the transportation infrastructure had positive effects on enterprises. For instance, Ataek *et al*. found that railway construction caused both manufacturers and markets to expand. Based on a study on highways in India, Ghani *et al*. (2016) revealed the transportation infrastructure's effects on manufacturing organization and efficiency were conducive to economic development. Based on city panel data, Xie and Wang (2020) examined the effects of intra-regional and inter-regional transportation infrastructure on the distribution of industrial activity and found that improvement in the inter-regional transportation infrastructure could optimize the distribution of production factors. In addition, many studies have examined the economic effects of the transportation infrastructure from such perspectives as employment (Dong and Zhu, 2016), economic spillovers (Bian *et al*., 2019), enterprise operation (Zhu *et al*., 2019; Yang *et al*., 2019) and total factor productivity (TFP) (Liu *et al*., 2010). Overall, relevant studies suggest that the transportation infrastructure has significantly positive effects on regional economic integration and factor market integration, and helps stimulate the development of relevant industries, creating potential social benefits and promoting industrial clustering and local economic development by tapping into market demand and expanding the scale of production.

2.2 Determinants of the Site Selection of Enterprises

In their site selection, enterprises tend to consider the desirability for a target region and such constraints as their own characteristics, and strive to locate in a place that best meets their goals. Alfred Weber's theory of industrial location is underpinned by the idea that location determines the place of production, i.e. enterprises are attracted to places with the lowest cost of production and maximum cost savings. That the convenience of transportation is a key determinant in site selection is supported by the theory of new economic geography (Krugman, 1991). By enhancing an enterprise's ties with the external market, the transportation infrastructure increases the factor agglomeration force of regions at the center, and allows those on the periphery to develop under the spillover effect and form a dispersive force on regions at the center (Puga, 1999). The two forces counteract each other. The relative intensity of geographical economic agglomeration and dispersion influence the regional development layout and the spatial distribution of enterprises (Ottaviano *et al*., 2002).

Empirically, the existing literature is primarily concerned with the effects of infrastructure, economies of agglomeration and market potentials on the site selection of enterprises. In less developed countries, improvement of the domestic infrastructure will lead to an influx of enterprises, while improvement of the infrastructure in other countries may entice those enterprises to move overseas (Martin and Rogers, 1995). Without a doubt, the spatial agglomeration effect and the positive externalities of the urban economy are also key factors in the site selection of enterprises (De Bok and Van Oort, 2011). Based on the data of over 700 Japanese companies in the United States, Head *et al*. (1995) found that industrial agglomeration played an important role in the siting of enterprises. Based on Portuguese urban data, Guimaraes *et al*. (2000) studied the spatial choice of newly established overseas-funded factories and identified the pivotal effect of agglomeration economies on their site selection. The effects of market potentials on the siting of enterprises have also been extensively verified. With Japanese companies operating in Europe as subjects of research, Coughlin and Segev (2000) found that market potentials were extremely important to the site selection of enterprises. In addition, many studies have explored how FDI (Cheng and Stough, 2006), the time effect (Lin *et al*., 2018) and other factors influence the site selection of enterprises.

Most existing studies on the economic effects of the transportation infrastructure examined how the construction of infrastructure such as highways and railways influence economic growth from macroscopic perspectives, but their mechanisms of influence were simplistic, and only the positive effects of the transportation infrastructure were observed, without taking into account negative effects such as more stringent environmental regulation. Despite an abundance of research on the site selection of enterprises, most domestic studies in China have used the transportation infrastructure as the sole control variable to investigate the effects of market potentials, resource endowment and foreign investment on the site selection of enterprises (Ye and Ye, 2012; Zhou and Chen, 2013). Although a few studies analyzed site selection from the perspectives of accessibility and agglomeration, they did not take the upgrading of the transportation infrastructure into account, and instead focused their research on general manufacturing or foreign-funded enterprises (Zhang and Chen, 2006; Zhou *et al*., 2015). Few studies have specifically examined the relationship between the upgrading of the transportation infrastructure and the siting of polluting enterprises. Polluting enterprises, which contribute to economic growth, are a unique category of enterprises that need to be separately discussed. With the upgrading of the local transportation infrastructure, questions polluting enterprises face seem more complex than to other enterprises.

For local governments, access to transportation offers an attraction to business investment (Luo *et al*., 2015). Under the constraints of green development and environmental supervision, however, local governments have to turn away polluting enterprises (Wang *et al*., 2019). Therefore, it is worth researching how polluting enterprises enter and develop in a region and how their spatial layout changes after the upgrading of the transportation infrastructure. Since the high-speed railway serves as a good proxy for the transportation infrastructure, this paper employs the difference-in-differences (DID) method to examine the effects of a high-speed railway on the siting of polluting enterprises. We performed a heterogeneity analysis based on different levels of pollution, enterprise ownership, geographical location and environmental awareness, and tested the mechanism by which the launching of a high-speed railway would influence the siting of polluting enterprises from the perspectives of environmental cleanup, factor agglomeration and spatial integration.

3. Theoretical Analysis and Research Hypotheses

From Von Thünen's classical agricultural location theory to Alfred Weber's theory of industrial location and the neoclassical location theory, transportation infrastructure and economic agglomeration have been important factors in the site selection of enterprises (Long *et al*., 2017), including polluting enterprises. Like other enterprises, polluting enterprises seek to maximize profit and minimize cost. The difference is that polluting enterprises create environmentally harmful byproducts as well as useful commodities, making their establishment or relocation subject to more complex policy effects. According to the pollution haven hypothesis, polluting enterprises tend to locate in regions with less stringent environmental regulation. In other words, polluting enterprises tend to move from prosperous regions to less developed regions where environmental regulation is more relaxed. Hence, firms need to consider resource endowment, environmental regulation, transportation infrastructure and industrial policy when making a site selection. For a theoretical analysis of the intrinsic mechanism and determinants of the site selection of enterprises, we created the following theoretical model, referencing Krugman (1991) and other classical models of new economic geography.

Based on the center-periphery model, we assume that two regions (North and South) and two production factors, i.e. labor (L) and capital (K), exist. Each region has two production sectors A and M. A is the agricultural sector with perfect competition and constant return to scale, and only employs a labor factor. That is, products in the agricultural sector are homogeneous, with a fixed marginal output of labor input, but the intra-regional and inter-regional agricultural trade costs are not taken into account. M is the industrial sector and satisfies the conditions of Dixit-Stiglitz monopolistic competition. Each product in the industrial sector entails one unit of capital that has a fixed cost, and an iceberg cost exists in the transaction of industrial goods. However, there is a diverse range of industrial products with differentiated characteristics.

3.1 Consumer Behavior

Consumers simultaneously consume agricultural and industrial products, and their consumption function conforms to the Cobb-Douglas utility function:

$$U=C_M^{\mu}C_A^{1-\mu},\ \mu>0 \tag{1}$$

Where U is the consumer utility, C_M is the consumption of different sorts of industrial goods, C_A is the consumption of agricultural goods, μ is the share of spending on industrial goods, $(1-\mu)$ is the share of spending on agricultural goods, agricultural price is defined as p_A, and industrial price is defined as P_M. Consumer spending equals consumer income Y. Under the total spending constraint, when the consumer utility is maximized, we have:

$$\max U=C_M^{\mu}C_A^{1-\mu} \tag{2}$$

$$\text{s.t. } p_A C_A+P_M C_M=Y \tag{3}$$

C_M contains a diverse range of industrial goods. This paper employs the constant elasticity of substitution (CES) function to denote the consumption C_M of industrial goods and considers industrial goods as a continuous variable. The equation is as follows:

$$C_M=[\int_{i=0}^{n+n^*}c_{Mi}^{\rho}\mathrm{d}i]^{1/\rho} \tag{4}$$

c_{Mi} is the consumption of type i-th industrial goods, and n and n^* are the types of products made by local and nonlocal polluting enterprises. ρ is the intensity of consumers' diverse preferences, and its relationship with the elasticity of consumers' substitution σ is $\rho=(\sigma-1)/\sigma$. ρ's value is in the range of 0-1. The closer it is to 1, the weaker the intensity of consumers' diverse preferences becomes, and vice versa. When the consumption of industrial goods M is considered, their combined consumption C_M is constant, and spending on the consumption of industrial goods has to be minimized. With the price of type i industrial goods denoted by p_{Mi}, we have:[1]

$$c_{Mi}=\mu Y(p_{Mi}^{-\sigma}/P_M^{1-\sigma}) \tag{5}$$

3.2 Producer Behavior

In the industrial sector, each differentiated product has an increasing return to scale. The optimal pricing strategy for manufacturers is markup pricing, and at the equilibrium, profit for each manufacturer

[1] Please refer to the attachment on the website of *China Industrial Economics* (http://ciejournal.ajcass.org).

is 0. No enterprise makes products that are identical to those of other enterprises. That is to say, the number of enterprises equals the number of product categories. Enterprises are free from business diversification and collusion, and the fixed cost of each product is the same, and so is the marginal cost. Enterprise production requires the input of F units as fixed input, and each unit of output entails a variable input of a_M units of labor. Given the environmental impact of the production of polluting products, the government has imposed an environmental tax θ on polluting products (tax θ for each unit of product, assuming that all industrial enterprises pollute and that the environmental tax is collected only in prosperous cities). Hence, their cost function is $\omega(F+a_M x)+\theta x$. We make $k=1+\theta/(a_M\omega)$, and the cost function can be written as $\omega(F+ka_M x)$, where x is the output of enterprises, and ω is the wage of workers. According to this cost function, we derive the following firm profit function for manufacturing type i differentiated product:

$$\pi_i=p_{M_i}x_i-\omega(F+ka_M x_i) \tag{6}$$

Where x_i is the output of type i differentiated product. Given the absence of savings, the total income of the economic system equals total spending, and total output equals total demand. Equation (5) can be transformed into:

$$x_i=\mu E^T(p_{Mi}^{-\sigma}/P_M^{1-\sigma}) \tag{7}$$

Where E^T is the total spending of the economic system. Substituting it into equation (6) for derivation gives us:

$$p_{M_i}=\omega ka_M/(1-1/\sigma) \tag{8}$$

3.3 Siting of Enterprise Production

Following the "iceberg" transaction cost, although there is no transportation cost for industrial goods in the local consumer market, transactions between the South and the North are subject to the cost of transportation. The sale of one unit of product in another region necessitates the transportation of τ units of product ($\tau\geq1$). Among them, $\tau-1$ units of product become "melted" during transportation. If p_M denotes the local product price for an industrial enterprise in the North, the product price for the enterprise becomes $p_{M_i}{}^*=\tau p_{M_i}$ in the South. It is assumed that the sales volume for enterprise i based in the North is c_{M_i} at the sales price of p_{M_i}, and the sales volume in the South is $c_{M_i}{}^*$ at the sales price of $p_{M_i}{}^*=\tau p_{M_i}$.

$$\pi_i=p_{M_i}x_i-\omega(F+ka_M x_i) \tag{9}$$

The equation can be transformed into the following by substituting equation (8) into equation (9):

$$\pi_i=\frac{p_{M_i}x_i}{\sigma}-\omega F \tag{10}$$

Where $p_{M_i}x_i=p_{M_i}c_i+p_{M_i}\tau c_{M_i}{}^*$. It can be learned from equation (5) that $c_{M_i}=\mu Y\frac{p_{Mi}^{-\sigma}}{P_M^{1-\sigma}}$, $c_{M_i}{}^*=\mu Y^*\frac{(\tau p_{Mi})^{-\sigma}}{(P_M^*)^{1-\sigma}}$. Substituting it into equation (10) gives us:

$$\pi_i=\frac{\mu(Y+Y^*)}{\sigma(n+n^*)}\left[\frac{s_E}{s_n+\phi(1-s_n)}+\phi\frac{1-s_E}{\phi s_n+(1-s_n)}\right]-\omega F \tag{11}$$

Where $s_E=Y/(Y+Y^*)$ is spending in the North as a share of total spending, and $1-s_E$ is spending in the South as a share of total spending. $\phi=\tau^{1-\sigma}$ is trade freedom, and $0\leq\phi\leq1$. A higher level of inter-regional transportation infrastructure corresponds to a higher degree of trade freedom. s_n is the number of enterprises in the North as a share of total enterprises in the economic system.

As can be learned from equation (11), although environmental regulation has no direct impact on profit, environmental tax will affect household spending and induce wage growth ω, thus lowering firm profit. As such, this paper puts forth the following hypothesis:

Hypothesis 1: Due to environmental regulation, the profit of polluting enterprises suffers more in more developed regions, and upgrading the transportation infrastructure will only intensify this trend, as manifested in the falling number of polluting enterprises after a high-speed railway is put into service in the region.

By the same token, the profit function for enterprises in the South can be obtained. Under the equilibrium state, the profit is the same in each region $\pi=\pi^*$. Thus, the spatial distribution of enterprises s_n at the equilibrium state can be obtained as follows:[2]

$$s_n=\frac{1}{2}+\frac{1+\phi}{1-\phi}(s_E-\frac{1}{2}) \tag{12}$$

As can be learned from equation (12), the ratio of polluting enterprises to total enterprises in the North is subject to the joint effects of trade freedom ϕ and spending in the North s_E, but the ultimate result is contingent upon the status of city development. For the convenience of analysis, this paper assumes that the North and the South are developed and less developed regions, respectively. For the North, upgrading the transportation infrastructure will theoretically increase trade freedom and reduce the transportation cost of imported goods. Yet the high-speed railway as an example in this paper is primarily a qualitative improvement - instead of a quantitative expansion - of the transportation infrastructure. In prosperous regions, in particular, upgrading the transportation infrastructure has a limited marginal effect on trade cost. Hence, the role of s_E becomes particularly important. s_E denotes the share of spending in the North, and spending is correlated with labor and capital in the locality, both of which are influenced by the transportation infrastructure.

After a transportation infrastructure upgrade, developed regions will experience a factor price hike, as manifested in a stronger market competition effect or market crowding effect, and the environmental tax will induce an increase in the living cost effect, prompting labor and capital to flee, as reflected in decreasing s_n. The falling share of polluting enterprises in the North means that more enterprises move to the less developed South. Normally, when polluting enterprises are established in the North, the economic system has to pay both a production cost and an environmental tax. When polluting enterprises are established in the South, however, consumers in the North only have to pay a production cost and a decreasing transportation cost, and the South only has to pay a production cost. Therefore, the economic system as a whole benefits when polluting enterprises are established in the South. As such, this paper puts forth the following hypothesis:

Hypothesis 2: The upgrading of the transportation infrastructure is normally followed by the migration of polluting enterprises to less developed regions.

4. Econometric Model and Variable Data Explanations

4.1 Econometric Model

To observe the effect of a high-speed railway on the siting of polluting enterprises, this paper creates a difference-in-differences (DID) model to control for other differences before and after the launching of the high-speed railway to separate the real policy effect. At the heart of this model is the creation of a DID estimator, but given the different launching dates of a high-speed railway for various cities, this paper employs multi-phase DID to create the following model for a description of inconsistent time points of individual treatment periods:

$$Y_{it}=\alpha+\beta HSR_{it}+\varphi Control_{it}+\mu_t+\gamma_i+\varepsilon_{it} \tag{13}$$

Where i and t are city i and period t. Explained variable Y_{it} is the number of new polluting enterprises in city i and year t. HSR_{it} is the dummy variable for the launching of a high-speed railway,

[2] For the derivation process, please refer to the attachment on the website of *China Industrial Economics* (http://ciejournal.ajcass.org).

and is 1 if the high-speed railway was put into service in city *i* in year *t*. Otherwise, it is 0. $Control_{it}$ are other control variables, and refers to the impact of key factors other than the high-speed railway on the siting of polluting enterprises. μ_t is the time fixed effect, and γ_i is the individual fixed effect, which more precisely reflect temporal and individual characteristics and mitigate the problem of bias due to the omission of variables. According to the design of the DID model, β is the core estimated coefficient of the explanatory variable in this paper, and denotes the impact of a high-speed railway on the siting of polluting enterprises.

4.2 Data Source

This paper selects 270 cities in China (excluding Hong Kong, Macao and Taiwan) in 1999-2013 as research samples. Data of polluting enterprises are from the database of China's industrial enterprises, and GDP, industrial value-added, foreign direct investment (FDI), total population and total pollution treatment investment are from the *China City Statistical Yearbook*. Consumer price indices of various prefecture-level cities are from the database of China's economic and social development statistics. This paper has referenced Lu and Chen (2009) for the treatment of relevant data. To control for heteroscedasticity and statistical error, our model takes the logarithms of all explanatory variables.

4.3 Variable Specification

(1) Explained variable. The explained variable in this paper is the number of newly established polluting enterprises in cities. For our analysis of heterogeneous levels of pollution, this paper divides polluting sectors into heavily polluting, moderately polluting and lightly polluting industries, and calculates annual increases in the numbers of heavily polluting, moderately polluting, lightly polluting and non-polluting enterprises as the explained variable. Polluting enterprises are divided into overseas-funded, state-owned, private and other enterprises.

(2) Core explanatory variable. This paper's core explanatory variable is the launch of a high-speed railway with the dummy variable of whether China's prefecture-level cities had access to a high-speed railway in 1999-2013. Referencing Bian *et al*. (2019), this paper defines the launching of the earliest high-speed railway in a prefecture-level city as the date for the launching of the high-speed railway if the city had access to more than one high-speed railway. For cities with the first high-speed railway launched at the end of the year, this paper adopts a one-year lag treatment.

(3) Control variables: Aside from the core explanatory variable of the launching of a high-speed railway, this paper also needs to control for other factors that influence the siting of enterprises. Normally, enterprises choose to locate in a region they consider optimal based on certain considerations. The rational siting of economic entities results in the agglomeration and dispersion of economic activity in an advantageous region. Many factors are at play behind site selection. The traditional location theory believes that apart from transportation, enterprises also consider such factors as industrial agglomeration, market mechanism and resource endowment.

This paper employs the following control variables: (i) Population density (*density*): The density or abundance of population has an impact on the labor supply. Less populous cities are short on labor force, the scarcity of which means a higher labor cost for new enterprises. Labor shortage may impede the establishment and operation of enterprises. (ii) Size of the local economy (*pgdp*). Economically underdeveloped regions cannot sustain industrial development, nor can they provide a conducive business climate. Hence, the level or scale of economic development is taken as a proxy for a city's all-round capabilities and business climate. A larger local economy normally comes with more complete market and legal systems and a more pro-business environment. This paper selects GDP as a proxy for the size of the local economy. (iii) Industrial structure (*stru*). The industrial structure is vital for the site selection of enterprises in terms of upstream and downstream supply and demand, market opportunities, and market potentials. This paper employs the share of the tertiary industry in the GDP as a proxy for the industrial structure. (iv) Level of information and communication technology (ICT) application (*infor*). Information exchange and knowledge sharing influence the access of firms to market and technological advancement. ICT-savvy cities are more capable of exchanging information with the outside world, making it easier for enterprises to access technology, market and information. This paper selects the number of internet users as a proxy for the level of ICT application. (v) Level of pollution (*pollu*). With growing environmental awareness, environmental quality has become a key determinant in the site selection of enterprises. Environmental expectations and the level of pollution vary across different types of industrial sectors and enterprises, which choose to locate in different places. This paper selects the amount of per capita industrial soot emissions as a proxy for the level of pollution. (vi) Financing potentials (*finan*). Prosperous regions - especially those with financial strengths - are more attractive to enterprises for their advantages in terms of business registration, corporate control, financial intermediation, and access to credit. This paper selects the year-end balance of loans from financial institutions as a proxy for financing potentials. (vii) External openness (*fdi*). Integration into the global economy and regional openness are also key considerations for the site selection of enterprises. To some extent, external openness reflects integration between the regional economy and the international market. This paper selects the actual amount of current-year FDI in various prefecture-level cities as a proxy for external openness. (viii) Urban freight transportation capacity (*freight*). Aside from a high-speed railway, access to highways and railways also influences the site selection of enterprises. This paper selects the total highway and railway freight transportation of each prefecture-level city as a proxy for urban freight transportation capacity.

Aside from the above factors, the natural attributes of cities - such as natural resources, climate, geography, soil, water or proximity to mineral and other raw materials resources - also play an important role in the site selection of enterprises (Ellison and Glaeser, 1999). Moreover, a region's culture is rooted in its historical and geographical characteristics, and features unique modes of behavior and thinking. Before choosing to locate in a place, firms survey the local society, history and culture, such as language, ethnicity, education, customs, and values. By controlling for dual temporal and spatial fixed effects, this paper prevents bias in parametric model estimation due to the omission of variables.

5. Baseline Regression and Further Extended Analyses

5.1 Baseline Regression Analysis

Baseline regression results are shown in Table 1. Results in Columns (2) through (4) suggest that after the inclusion of control variables, the launching of a high-speed railway has a negative effect on the acceptance of polluting enterprises, i.e. access to a high-speed railway significantly reduced the entry of polluting enterprises. A likely reason is that the launching of a high-speed railway presents local governments with a broader choice of investors, making polluting enterprises less appealing. This creates a crowding out effect on polluting enterprises. Thus, Hypothesis 1 is verified. This section will discuss the mechanism of this effect.

5.2 Equilibrium Trend Test

The DID model requires the treatment group and control group to share the same trend before the occurrence of an event. Referencing Beck *et al*. (2010), we created a string of dummy variables depicting the year of the launching of a high-speed railway, and d_1 through d_5 are the dummy variables for the period before the launching of the high-speed railway. Among them, d_1 is the year preceding the launching of the high-speed railway, marked as 1, and the rest are 0; by the same token, d_2 is two years preceding the launching of the high-speed railway, marked as 2, while the rest are 0, and so on and so forth. $d1$ through $d5$ are dummy variables for the period after the launching of the high-speed railway, defined under the same principle as for d_1 through d_5. *current* is the dummy variable

Table 1: Baseline Regression Results

	(1)	(2)	(3)	(4)
HSR	-5.1537	-13.0206***	-16.1690***	-12.2426**
	(3.8721)	(4.8549)	(5.9985)	(5.7323)
density		9.6276***	11.7704	11.2637*
		(2.1467)	(9.6055)	(6.2668)
pgdp		2.2065	20.7988***	12.2637**
		(2.9198)	(3.8346)	(5.4966)
stru		-49.0521***	-119.9836***	-96.9077***
		(17.6451)	(33.1207)	(31.3694)
infor		3.3917***	2.1072***	1.5310
		(0.3735)	(0.3124)	(2.1584)
pollu		-2.0804*	-2.6257**	0.6289
		(1.0744)	(1.3199)	(1.2077)
finan		-2.3157	-15.8390***	21.0884***
		(2.2232)	(2.7453)	(7.1277)
fdi		2.9095***	-0.5889	0.0140
		(1.1083)	(1.2746)	(1.1152)
freight		6.6056***	1.1298	1.1890
		(2.4236)	(3.0091)	(2.9035)
_cons	26.5176***	-101.7832***	34.2495	-458.1004***
	(1.7504)	(27.1974)	(58.0410)	(122.6917)
Temporal effect	No	No	No	Yes
Spatial effect	No	No	Yes	Yes
R^2			0.0709	0.2188
N	3,914	2,717	2,717	2,717

Notes: ***, ** and * denote significance at 1%, 5% and 10%, respectively; numbers in parentheses are robust standard errors. The same below. In Columns (1) through (4), time effect refers to the time fixed effect, and spatial effect refers to the fixed effect of city.

for the current period of the launching of the high-speed railway. An equilibrium trend test is performed for the study using a dynamic DID model. As shown in the results of Figure 1, the coefficients of the period preceding policy implementation are all insignificant. That is to say, there is no significant difference in the acceptance of polluting enterprises between the treatment group and the control group prior to the launching of the high-speed railway, which satisfies the parallel trend hypothesis for the DID model. Judging by coefficients *d*2 through *d*5, the launching of the high-speed railway has a significant and lasting effect of exclusion on the siting of polluting enterprises, which further verifies the above-mentioned view that the launching of a high-speed railway makes local governments less willing to accept polluting enterprises.

5.3 Robustness Analysis

To further test the robustness of the above conclusions, we included control variables and substitution variables, removed special enterprises, and performed a counterfactual analysis to test the robustness of the regression results. Among them, control variables include the manufacturing cluster effect, market potentials, resource endowment and policy effect.

(1) Control for the manufacturing cluster effect. Cluster effect refers to the economic effect of the geographical proximity of a large number of enterprises concentrated in a specific geographical region.

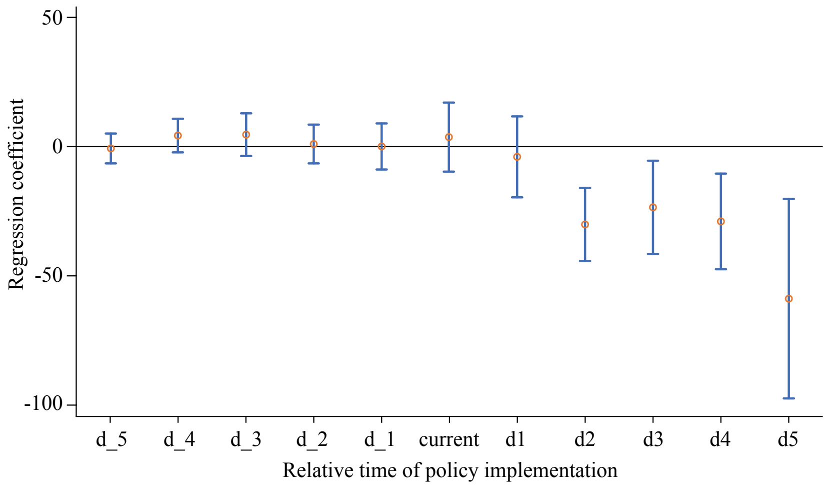

Figure 1: Results of Equilibrium Trend Test

Individual manufacturers cannot gain an upper hand when isolated from others. Manufacturing clusters provide enterprises with a conducive environment. In addition to lowering cost, facilitating transactions and boosting productivity, the concentration of related firms is also conducive to the spillovers of knowledge and technology, competition, coordination, innovation, and business startup (Chen and Hu, 2008). This paper adopts manufacturing workforce as a proxy for manufacturing clustering. Column (1) of Table 2 controls for the clustering effect, and the results remain significant.

(2) Control for market potentials. New economic geography stresses that interactions between production cost and market potentials determine the site selection of firms and thus induce change in the layout of economic activity (Krugman and Venables, 1995). Normally, firms will locate in a place close to the market to increase productivity and realize product value. Firms aim to add value by selling goods or offering services, and the market offers the space or vehicle for value addition. Countries and regions with broad market potentials are more attractive to firms. Results presented in Column (2) of Table 2 show that the effect remains significant with the same direction after controlling for market potentials.

(3) Control for resource endowment. Specialization based on comparative advantages or return on scale relies on unique regional resource endowment, which attract different types of firms (Missiaia, 2019). Hence, the endowment of labor and capital has a strong effect on the spatial distribution of manufacturing. To control for the effect of factor endowment on the site selection of enterprises, we employed the ratio between labor and capital as a proxy for the difference in resource endowment and controlled for it. As shown in Column (3) of Table 2, results remain significant after controlling for resource endowment.

(4) Control for policy effect. Government policies influence the site selection of enterprises. For instance, tax incentives and investment policy preferences attract an influx of businesses. Polluting enterprises are often unwelcome in prosperous regions with stringent environmental regulation, and tend to move to less developed regions where environmental standards are comparatively relaxed or loosely enforced. In China, the market access policy for polluting enterprises is set at the provincial level and is subject to change over time. To control for the effect of policy change on polluting enterprises, we have set an interaction term between the provincial fixed effect and the time effect with results shown in Column (4) of Table 2. The results remain significant after controlling for the policy effect.

(5) Substitution of variables. To further verify the robustness of the results, we employed the degree centrality method to estimate the centrality of a high-speed railway network referencing Deng and Xu (2015) and substituted the original core explanatory variable for a test. The centrality of the high-speed

railway network may well reflect the status of a city node in the high-speed railway network. P_i is the centrality of the high-speed railway network, and $P_i = m_i/(n-1)$, where n is the total number of node cities, and m_i is the number of nodes in the high-speed railway network directly connected to city i. P_i is the degree of a city's direct connections to other node cities. A higher value of P_i means there are more direct connections to node cities and more conveniences or resource allocation rights of the city in the entire high-speed railway network. We substituted this indicator with the variable for the launching of a high-speed railway, as shown in Column (5) of Table 2, and the results remain significantly negative. In addition, this paper has also substituted the original explained variable with the variable of outflow of polluting enterprises from a city to verify the impact of the launching of a high-speed railway on polluting enterprises from another angle.[3]

(6) Removing enterprises of a special nature. Enterprises in a few sectors - such as mining and those with close links between upstream and downstream sectors - have special siting requirements. For state-owned enterprises (SOEs) and overseas-funded enterprises, their site selection could be subject to policy interference. In counting polluting enterprises, we removed SOEs, overseas-funded enterprises, mining enterprises, and those in related sectors. A new explained variable was substituted into the baseline model for the regression with results shown in Column (6) of Table 2, and the results remain significantly negative.

(7) Counterfactual test. Referencing Fan and Tian (2013) *et al*., we performed a counterfactual test by altering the time point of the policy implementation to further verify the robustness of the results. Aside from the launching of a high-speed railway, other potential policy effects may also influence the site selection of polluting enterprises, causing a bias in our estimated results. To clarify the effects of those factors, we assumed the launching of a high-speed railway to be earlier by one to six years, denoted as *HSR*_1, *HSR* _2, *HSR*_3, *HSR*_4, *HSR*_5 and *HSR*_6. The new variables were substituted

Table 2: Robustness Test

	(1)	(2)	(3)	(4)	(5)	(6)
HSR	-12.1218**	-12.0988**	-11.5034**	-13.5029***	-21.6661***	-11.0646***
	(5.8328)	(5.8380)	(5.7408)	(5.0947)	(7.5169)	(4.1918)
agglo	-0.7275	-0.7678	8.8504**	2.2524	2.4423	0.7386
	(2.9607)	(2.9684)	(3.7696)	(2.9222)	(2.9511)	(2.4086)
market		0.5936	2.1185	1.1373	0.8414	1.4976
		(2.9352)	(2.9042)	(3.3786)	(3.4074)	(2.7991)
endow			-15.8868***	-11.8283***	-11.8593***	-10.4340***
			(3.8262)	(2.8683)	(2.8693)	(2.7165)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Province × time	No	No	No	Yes	Yes	Yes
R^2	0.2188	0.2188	0.2236	0.5339	0.5351	0.5027
N	2,717	2,715	2,713	2,713	2,713	2,713

Note: Regression results have omitted control variables and constant terms. Fixed effects include the time fixed effect and the city fixed effect. The same below.[4]

[3] Refer to the attachment on the website of *China Industrial Economics* (http://ciejournal.ajcass.org).
[4] For complete regression results, please refer to the website of *China Industrial Economics* (http://ciejournal.ajcass.org).

Table 3: Counterfactual Test

	(1)	(2)	(3)	(4)	(5)	(6)
*HSR*_1	3.7933 (4.0271)					
HSR _2		-2.6815 (3.9396)				
*HSR*_3			5.0988 (3.9869)			
*HSR*_4				4.1896 (3.2750)		
*HSR*_5					1.6564 (3.5992)	
*HSR*_6						-0.8801 (3.9217)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Province × time	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.5308	0.5307	0.5311	0.5310	0.5307	0.5306
N	2,713	2,713	2,713	2,713	2,713	2,713

into the baseline model for the regression. If the new dummy variable for the launching of a high-speed railway was still significant, the implication was that the change in site selection by polluting enterprises was primarily due to the launching of the high-speed railway, thus verifying the robustness of the above conclusions. Table 3 reports the overall regression results after substituting the lag terms of one to six years for the launching of a high-speed railway. On the whole, the coefficients of the new explanatory variable are insignificant. This explains that the launching of a high-speed railway is a primary factor influencing the site selection of polluting enterprises, which verifies the robustness of the above conclusions.

5.4 Heterogeneity Analyses

Unique conditions, attributes or regions of enterprises may have differentiated effects on the regression results. Given the differences in the level of pollution, ownership, geographical conditions, level of development and environmental awareness between enterprises, we further performed a series of heterogeneity analyses.

(1) Test of heterogeneity in the level of pollution. The launching of a high-speed railway has differentiated effects on the site selection of enterprises with different levels of pollution. As presented in the results shown in Table 4, Columns (1) through (3) suggest that with other factors held constant, a high-speed railway has negative effects on the site selection of lightly, moderately and heavily polluting enterprises alike, which are all very significant. The effects on non-polluting enterprises, however, are insignificant. A high-speed railway prompts a massive talent flow and infrastructure construction, causing cities to expand. Growing public environmental awareness leads cities to pursue green and low-carbon development, raising the barriers to entry for polluting enterprises.

(2) Test of heterogeneity in enterprise ownership. As existing studies have found, enterprises of different ownership types are subject to different policy preferences (Yin and Lu, 2004; Zhou *et al.*,

Table 4: Regression Results for Enterprises with Different Levels of Pollution

	(1) Lightly polluting enterprises	(2) Moderately polluting enterprises	(3) Heavily polluting enterprises	(4) Pollution-free enterprises
HSR	-5.3816***	-3.8728**	-4.2486*	-0.2029
	(1.7838)	(1.6035)	(2.1583)	(0.1610)
Control variables	Yes	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes	Yes
Province × time	Yes	Yes	Yes	Yes
R^2	0.4446	0.4744	0.5440	0.3060
N	2,713	2,713	2,713	2,713

2010). We divided polluting enterprises into overseas-funded, state-owned, private and other enterprises. Among them, state-owned enterprises (SOEs) include state-controlled and collectively controlled industrial enterprises, and overseas-funded enterprises include those controlled by investors from Hong Kong, Macao and Taiwan and those with overseas investment, and privately controlled enterprises and other enterprises are classified as private and other enterprises. Results are shown in Table 5. As can be seen from the estimated coefficients, the effect of a high-speed railway is negative only for private and other enterprises. A possible reason is that the launching of the high-speed railway could be followed by an influx of capital and enterprises (Giroud, 2013), making it more likely for local governments to restrict private and other polluting enterprises. One effect of the policy to promote local investment, however, is the incentivization of local governments to attract overseas-funded enterprises (Shen, 1999), which enjoy relatively relaxed entry thresholds. Despite the impact of environmental policy on polluting enterprises, the siting of SOEs is primarily influenced by local and upper-level governments, and the effect of the launching of a high-speed railway is insignificant.

(3) Test of heterogeneity in geographical location. As existing studies have shown, expectations for environmental quality vary across regions with different levels of development. In more prosperous regions, the public expects a cleaner environment (Jun *et al*., 2011). According to the environmental Kuznets curve, public environmental awareness increases with economic growth, and income is in an inverted U-shaped relationship with environmental pollution (Dinda, 2004). This paper divides China into eastern, central and western regions to examine the differences in which a high-speed railway influences the siting of polluting enterprises. As shown in Columns (1)-(3) of Table 6, *HSR×east*, *HSR×mid* and *HSR×west* respectively denote the interaction terms between the dummy variables of China's eastern, central and western regions and the launching of a high-speed railway. The following regression results reveal a modulating effect of geographical difference on the results. For the eastern region, access to a high-speed railway has indeed made polluting enterprises less welcomed, and potentially has a crowding out effect on polluting enterprises. For the central and western regions, however, a high-speed railway has a significantly positive modulating effect on the siting of polluting enterprises. A possible reason is that the central and western regions are still focused on economic growth even at the expense of some environmental pollution. With a comparatively relaxed environmental threshold and a robust demand for development, the central and western regions have hosted many polluting enterprises, including some relocated from the eastern region (Peng *et al*., 2013).

(4) Test of heterogeneity in the level of city development. The level of regional economic development may have a modulating effect on the relationship between a high-speed railway and polluting enterprises. In this paper, the level of each city's economic development is measured by

Table 5: Regression Results for Enterprises of Different Ownership Types

	(1)	(2)	(3)
	Overseas-funded enterprises	State-owned enterprises	Private and other enterprises
HSR	-0.0506 (0.7353)	-0.2495 (0.2075)	-13.2032*** (4.7974)
Control variables	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes
Province × time	Yes	Yes	Yes
R^2	0.4063	0.3894	0.5271
N	2,713	2,713	2,713

Table 6: Regression Results Considering the Differences of Eastern, Central and Western Regions

	(1)	(2)	(3)
HSR×east	-19.2659** (9.4159)		
HSR×mid		14.0124* (8.3780)	
HSR×west			16.9346** (7.8344)
HSR	-3.8474 (2.3569)	-19.2183** (8.2016)	-15.0431*** (5.4781)
Control variables	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes
Province × time	Yes	Yes	Yes
R^2	0.5357	0.5348	0.5344
N	2,713	2,713	2,713

the GDP. The top one third most prosperous Chinese cities are defined as cities with a high level of economic development, denoted by the dummy variable of *high*, and those at the medium one third and bottom one third levels are marked as *med* and *low*. *HSR×high*, *HSR×med* and *HSR×low,* respectively, denote the interaction between the launching of a high-speed railway and those dummy variables.

As shown in Table 7, Columns (1) through (3) indicate that the launching of a high-speed railway has a significantly negative impact on the acceptance of polluting enterprises by prosperous cities, while the effect is the opposite for cities with moderate or low levels of economic development. That is, polluting enterprises are rejected by prosperous cities and welcomed by less prosperous ones. The implication is that the level of economic development has a modulating effect on the relationship between the high-speed railway and the siting of polluting enterprises, as manifested in the relocation of polluting enterprises from more prosperous to less prosperous cities.

Referencing Li and Luo (2020), we divided cities into large cities and small and medium-sized ones, using *HSR×big* to denote the interaction between large cities and the launching of a high-speed railway

Table 7: Regression Results Considering Different Levels of City Development

	(1)	(2)	(3)	(4)	(5)
HSR×high	-15.0073* (7.7671)				
HSR×med		11.4592* (6.8888)			
HSR×low			13.0029 (9.4784)		
HSR×big				-14.9845** (7.0890)	
HSR×small					18.4969*** (6.7641)
HSR	-4.1353 (3.3899)	-16.8690** (6.7198)	-14.5698*** (5.4050)	-2.7030 (4.9018)	-18.1603*** (6.1413)
Control variables	Yes	Yes	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes	Yes	Yes
Province × time	Yes	Yes	Yes	Yes	Yes
R^2	0.5352	0.5346	0.5343	0.5352	0.5357
N	2,713	2,713	2,713	2,713	2,713

and *HSR×small* to denote the interaction between small and medium-sized cities and the launching of a high-speed railway. Results are shown in Columns (4) and (5) of Table 7. Access to a high-speed railway will make polluting enterprises less appealing to large cities, and the reverse is true for small and medium-sized cities. As a result, the launching of a high-speed railway will prompt polluting enterprises to relocate from large cities to small and medium-sized ones.

(5) Test of heterogeneity in environmental awareness. Research shows that regional environmental awareness has a major impact on the acceptance of polluting enterprises (Cheng and Liu, 2018). The launching of a high-speed railway may influence the establishment or relocation of polluting enterprises. In this paper, a city's environmental awareness is measured by the integrated utilization rate of industrial solid waste, the domestic water treatment rate, and the harmless disposal rate of domestic waste. Cities with the three indicators above average are defined as environmentally conscious cities, marked as 1, and those below average are marked as 0, and the three dummy variables are denoted by *solid*, *sewage* and *garbage*. *HSR×solid*, *HSR×sewage* and *HSR×garbage,* respectively, denote the interaction between the launching of a high-speed railway and those dummy variables. As shown in the results of Table 8, the launching of a high-speed railway has a significant negative impact on the acceptance of polluting enterprises by environmentally conscious cities, especially those with a high domestic wastewater treatment rate and a harmless disposal rate of domestic waste, i.e. the local governments of environmentally conscious cities were more unwelcoming to polluting enterprises after the launching of a high-speed railway. This indicates there is a modulating effect of local environmental awareness on the relationship between a high-speed railway and the site selection of polluting enterprises.

6. Analysis of the Mechanism of Influence

A high-speed railway has complex effects on the siting of polluting enterprises. It may greatly

Table 8: Regression Results Considering Different Levels of Environmental Awareness

	(1)	(2)	(3)
HSR×solid	-9.7055 (6.4650)		
HSR×sewage		-14.7380* (7.5426)	
HSR×garbage			-12.4138* (6.8634)
HSR	-6.3358* (3.5091)	-2.9376 (3.4161)	-4.9261 (3.0112)
Control variables	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes
Province × time	Yes	Yes	Yes
R^2	0.5344	0.5351	0.5348
N	2,713	2,713	2,713

improve regional accessibility and the business climate, and create conditions for economic development and factor agglomeration. Yet access to a high-speed railway may also raise public expectations of environmental quality, raising barriers to entry for polluting enterprises. In this section, we analyze the effects of a high-speed railway on the site selection of polluting enterprises from three aspects: The environmental cleanup effect, factor agglomeration and spatial integration.

6.1 Environmental Cleanup Effect

According to the environmental Kuznets curve, the transportation infrastructure may promote local economic development and induce a demand for better environmental quality, and the government should enhance environmental regulation and promote its cleanup effect (Chen *et al.*, 2016). To verify whether a high-speed railway has influenced the siting of polluting enterprises under the cleanup effect, we performed a regression analysis of the launching of the high-speed railway and environmental cleanness, with results shown in Table 9. The explained variable in Column (1) is the environmental cleanup effect. The environmental effect of the high-speed railway results from a combination of factors, including local environmental regulation, environmental awareness, and clean technology adoptions. Referencing Zhu *et al.*'s (2011) indicator creation method, we created a composite indicator (*env*) based on the industrial SO_2 removal rate, the industrial COD removal rate, the integrated utilization rate of industrial solid waste, the domestic wastewater treatment rate, and the harmless treatment rate of domestic waste. Results indicate that the launching of the high-speed railway has a significantly positive effect on local pollution abatement, which verifies the environmental cleanup effect of access to a high-speed railway. The environmental cleanup effect of a high-speed railway is a key reason for the decreasing number of polluting enterprises, which is essentially due to the change in business climate amid economic growth. This finding is consistent with the above-mentioned baseline regression results.

6.2 Factor Agglomeration

The transportation infrastructure may influence a region's factor supply, as manifested in the change of factor abundance. A high-speed railway shortens the temporal and spatial distance between cities, allowing people to work and live in different cities, facilitates the flow of factors such as labor, information and technology between cities, and is a key driver of regional economic integration (Donaldson, 2018). Research indicates that the launching of a high-speed railway may attract talent and improve human capital (Ji and Yang, 2020). Labor is a key consideration in the site selection of enterprises, and a labor shortage has forced many businesses to suspend their operations. Compared with other production factors, the upgrading of the transportation infrastructure has a more significant effect on labor.

We verified that a high-speed railway creates conditions for labor flow, thus influencing the siting of polluting enterprises, with results shown in Column (2) of Table 9. The explained variable is the labor factor of cities, denoted by the average headcount of urban enterprises. Change in the urban workforce may reflect the supply and demand of the local labor market, which is a basic consideration in the site selection of polluting enterprises. The upgrading of the transportation infrastructure removes barriers to the labor flow between eastern, central and western regions, making the spatial distribution of factor resources less uneven. To some extent, this explains why polluting enterprises have been migrating from China's eastern region to the central and western regions, verifying Hypothesis 2. The high-speed railway facilitates the labor factor flow between China's eastern, central and western regions, allowing factor agglomeration to take place in the central and western regions, attracting polluting enterprises. By the same token, this verifies the results of Table 6 and is consistent with expectations.

6.3 Spatial Integration

According to new economic geography, transportation influences the spatial distribution of economic activity. Given the increasing return on wage, transaction cost and market externalities, firms tend to locate in places close to the market, giving rise to the spatial agglomeration of economic activity. As such, access to a high-speed railway will influence the spatial integration of cities along the route. Based on a reverse measurement of market segmentation, we tested the existence of the spatial integration effect of a high-speed railway. Referencing Lu and Chen (2009), we adopted the price index method to estimate the degree of market segmentation between adjacent cities. Results are shown in Column (3) of Table 9. Access to a high-speed railway has a positive effect on spatial integration. For an analysis of the spatial differences in the effect of spatial integration on site selection, we performed a regression analysis for the eastern, central and western regions, respectively.[5] Results suggest that in

Table 9: Results of the Mechanism Test

	(1)	(2)	(3)
	Environmental cleanup effect	Factor agglomeration	Spatial integration
HSR	0.0256^{*} (0.0146)	0.0669^{***} (0.0189)	0.1241^{**} (0.0490)
Control variables	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes
Province × time	Yes	Yes	Yes
R^2	0.6332	0.6030	0.7639
N	2,725	2,739	2,688

[5] Refer to the attachment on the website of *China Industrial Economics* (http://ciejournal.ajcass.org).

the eastern region, a higher degree of spatial integration makes it less likely for polluting enterprises to enter, and the reverse is true for the central and western regions. A possible reason is that cities in the eastern region are more prosperous with a higher degree of spatial integration and polluting enterprises face fiercer market competition (Zhou, *et al*., 2018), and the launching of a high-speed railway there is not conducive to the entry of polluting enterprises.

7. Conclusions and Policy Implications

7.1 Concluding Summary

With the launching of a high-speed railway in Chinese cities as a quasi-natural experiment, we employed data of 270 prefecture-level cities in 1999-2013 for a systematic study on the effect of upgrading the transportation infrastructure on the siting of polluting enterprises. We found a significant decrease in newly established polluting enterprises after the launching of the high-speed railway. Further research revealed differentiated effects of the high-speed railway on the siting of different types of polluting enterprises. For instance, we found a significant decrease in private and other polluting enterprises, while the effect on overseas-funded and state-owned enterprises is insignificant. In addition, the effect of a high-speed railway is geographically differentiated: Access to a high-speed railway makes polluting enterprises less welcome in the eastern region, and the reverse is true for the central and western regions. Public environmental awareness may also affect the relationship between a high-speed railway and polluting enterprises, i.e. other conditions being equal, polluting enterprises are less likely to locate in cities with a stronger public environmental awareness after the launching of a high-speed railway. We also found that the upgrading of the transportation infrastructure influenced the site selection of polluting enterprises under the mechanisms of environmental effect, factor agglomeration and spatial integration. Our conclusions are mainly as follows:

(1) The high-speed railway has generally restrained the growth of polluting enterprises. The launching of a high-speed railway has multifaceted effects on polluting enterprises. On the one hand, it helps enterprises raise efficiency, tap market potentials and reduce cost, thus attracting an inflow of enterprises with a strong "absorption effect". On the other hand, it raises public expectations for environmental quality, making localities less willing to host polluting enterprises, as reflected in a crowding out effect on polluting enterprises. Both effects jointly determine the net effect of the launching of a high-speed railway on the entry of polluting enterprises in a city. According to our analysis, the crowding out effect outweighs the absorption effect.

(2) Access to a high-speed railway has sped up the flow of polluting enterprises to the central and western regions. While a better transportation infrastructure contributes to growing public environmental awareness, it also allows central and western regions to access factors and markets and thus attract polluting enterprises. The spatial integration effect of a high-speed railway will also intensify market competition in the eastern region, limiting market potentials and profitability. The combination of various factors has led polluting enterprises to relocate to China's central and western regions.

(3) The upgrading of the transportation infrastructure has heterogeneous effects on the site selection of polluting enterprises. Specifically, the high-speed railway will increase regional differentiation. While the high-speed railway brings about greater market potentials, deepens the division of labor, and boosts resource allocation efficiency, those effects are highly differentiated across regions and enterprises. For prosperous or environmentally conscious cities, polluting enterprises become less desirable after the launching of a high-speed railway. For the central and western regions, with a lower environmental threshold, access to a high-speed railway gives rise to factor agglomeration and makes them more attractive to polluting enterprises. For enterprises of different ownership types, overseas-funded and state-owned polluting enterprises are far less affected than private and other enterprises.

7.2 Policy Implications

It has been widely recognized that the high-speed railway and other transportation infrastructure contribute to economic development. The effects of a high-speed railway on the site selection of polluting enterprises are of great significance for China's regional development planning and policymaking on business environment, investment and environmental protection. Those effects should be brought to the full attention of the government and market entities. In this respect, this paper puts forth the following policy recommendations:

(1) We should promote market fairness and attach importance to business development. After an upgrade of the transportation infrastructure, local governments become less willing to host polluting enterprises, especially those of private ownership. We should improve laws and regulations on market access and business operations for polluting enterprises to unify the national market and level the playing field. Not only should localities cease to relax environmental regulation specifically for overseas-funded polluting enterprises, but also discrimination against private polluting enterprises should be abandoned as long as they meet environmental standards and operate lawfully. We should enhance supervision on polluting enterprises, hold them accountable for environmental damage, and standardize their clean operations. In addition, we should establish an environmental responsibility insurance or clean production fund for polluting enterprises in key sectors related to people's livelihoods and strategic national priorities, and keep environmental risks under close surveillance.

(2) We should prevent the old path of "treatment after pollution" from being repeated in the central and western regions. The upgrading of the transportation infrastructure has increased the spatial flow of production factors. The rising environmental threshold and scarcity of land and labor in the eastern region have prompted numerous polluting enterprises to relocate to the central and western regions. Despite the priority of economic development to narrow their gaps with the eastern region, the central and western regions face a tight constraint of environmental protection. Industrial development cannot take place at the expense of environmental degradation. We should create a science-based environmental permit system, accept some polluting enterprises according to local environmental capacity, enforce and improve environmental assessment, and implement ecological compensation measures to promote green development in host regions.

(3) We should closely follow polluting enterprises and focus our environmental protection efforts accordingly. Polluting enterprises - which emit waste gas, wastewater or solid waste - are the key targets of environmental surveillance. Simply punishing, prohibiting or relocating polluting enterprises is not enough. What matters more is to make great efforts to build environmental facilities. In many cases, the relocation of polluting enterprises is not matched by investment in environmental treatment facilities such as wastewater and solid waste treatment plants. The government should prevent a resource mismatch in which fiscal funds continue to flow into government-led environmental projects in the eastern region, whereas polluting enterprises have relocated to the central and western regions.

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