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High-Speed Railway Facilities, Intercity Accessibility and Urban Innovation Level—Evidence from Cities in Three Chinese Megacity Regions

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Abstract: This paper investigates the impact of high-speed railways (HSR) on urban innovation levels by improving intercity accessibility. We employ prefecture city-level data within three megacity regions in China from 2009 to 2018. Using the number of invention patents granted as a proxy for the innovation level of a city, we find that HSR facilities significantly improve urban innovation levels through better regional intercity accessibility and that there is a diminishing effect as commuting time increases. The impact mechanisms of innovation improvement can be explained by an ever-increasing potential of interaction activities among talents and technology investment opportunities among cities. We contribute to the literature by highlighting the spatial attenuation impact of HSR on urban innovation levels as well as the underlying mechanisms. Particularly, talent interaction exerts a larger effect on urban innovation levels than technology investment opportunities. Moreover, we unravel the heterogeneous effects that more innovative cities and cities with double first-class universities gain more from the improved intercity accessibility brought by HSR. This research has policy implications that promoting HSR facilities improves innovation levels of cities with different resources.

Keywords: HSR; urban innovation level; intercity accessibility; megacity regions

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1. Introduction

High-speed railway (HSR) is a multifunctional infrastructure that can bring about unprecedented changes to many aspects of social life. Recent trends in HSR have spawned a proliferation of studies that documented the positive impact of HSR on different aspects of economic status, for instance, economic growth rate, transportation accessibility, employment, investment, production, land-use patterns, and so forth [1,2]. Central to the entire discipline of HSR is its direct economic effect, however its indirect effect on the economy remains less focused [3]. Hasan and Tucci (2010) have accentuated innovation as the primary productive force and continuous driving force of economic and social development [4]. This study gives an account of innovation as a substantial indirect effect of HSR, achieved by better intercity accessibility.

Innovation refers to an invention or a novel idea that could be applied to the economic sphere [5]. It is the product of the collaborative activities of individuals, institutions, and their interactions. Cities gather pivotal inputs for innovation, talented individuals, research funding, research institutions, and high-tech enterprises [6]. Florida, Adler, and Mellander (2018) subscribed to the belief that the city is an incubator for innovation and that this requires efforts from policymakers [7]. Of particular concern are mobility and accessibility issues, as they are the indispensable elements for urban innovation. It is well established that mobility and accessibility are fundamental properties of HSR [1] as they help to connect people and goods in various locations. Thus, HSR can promote urban innovation levels through improved accessibility, thus contributing to regional economies.

Notably, the impact of HSR facilities on the urban innovation level mainly remains on the regional level. Scholars have pointed out that creative activity clusters in cities or towns since the geographical distance is negatively associated with the possibility of cross-city scientific collaboration on research [7–9], and this tendency is enhanced year by year. The cooperation network is gradually turning into a regional network because of the ever more frequencies of collaborative activities across spatially close cities. As a result, Ma et al. (2014) concluded that the scientific and technological cooperation network in China has been gathering around cities, especially central cities [10].

Therefore, our study is based on three megacity regions in China, including the Beijing-Tianjin-Hebei region, the Yangtze River Delta region, and the Guangdong-Hong Kong-Macao region (See Figure 1). Three megacity regions are chosen as they are the most developed urban agglomerations in China with dense populations and leading achievements in various aspects. There are 73 cities in total in these three regions. There are 12 cities in the Beijing-Tianjin-Hebei region, 40 cities in the Yangtze River Delta region, and 21 cities in the Guangdong-Hong Kong-Macao region. In this study, Zhangjiakou, Bozhou, Hong Kong, and Macao are excluded due to the unavailability of data for some variables. Our study aims to investigate the relationship between HSR facilities, intercity accessibility, and the urban innovation level and the underlying mechanisms in these three Chinese megacity regions.

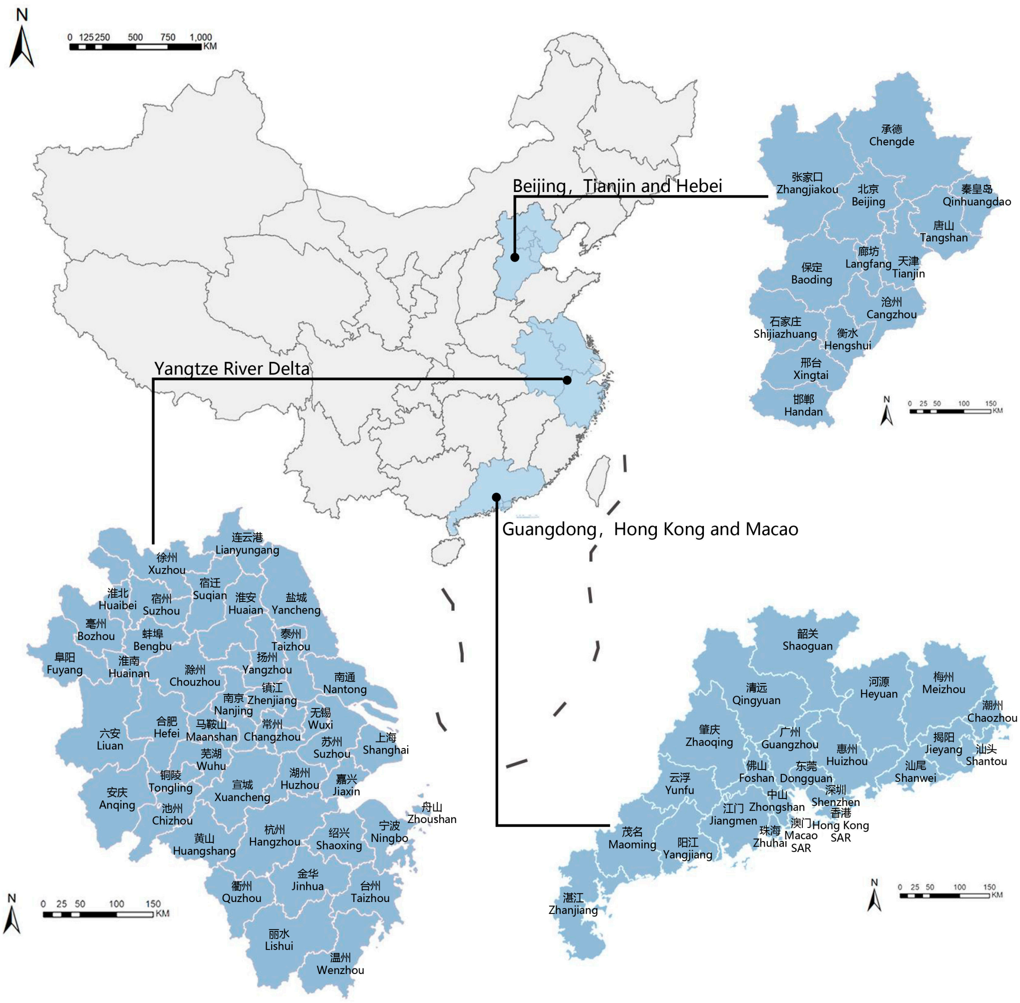

Figure 1. The location of three megacity regions in China.

However, a comparison of outcomes in cities with different HSR facility situations can hardly offer a consistent causal estimate of the impacts of the HSR facilities. The huge costs of infrastructure investment implied that cities that possess more HSR stations are possibly in a better economic climate and thus related to a higher innovation level [11]. We grapple with the challenge by exploiting slope and plain as two geographical instrumental variables to avoid the impact of economic factors in HSR investments.

The remaining part of the paper is organized as follows. Section 2 presents the literature related to the impact of HSR facilities on the urban innovation level. Section 3 explains the specifics of our data and empirical strategy. Section 4 provides the empirical results and the working mechanisms behind them. Moreover, we deal with robustness checks and heterogeneous tests in Section 4. In Section 5, we conclude and provide implications for policymakers as well as suggestions for further research.

2. Literature Review

A broad range of the literature has described the role of HSR facilities on different aspects of economics, including GDP growth [12], employment [13,14], investment [15], production [16], and land-use patterns [17]. These impacts are primarily achieved through the increased intercity accessibility brought by HSR [1]. Yet, only a small scale of the literature concentrates on the benefits of HSR on the urban innovation level [18,19].

2.1. The HSR, Intercity Accessibility, and Urban Innovation Level

The urban innovation level refers to the overall innovation capabilities that a city can practically express, namely a city's realized level of innovative output [20]. Transport infrastructure can promote the innovation level of cities in several ways. Particularly, the reason why we highlight the critical role of HSR is due to its functional property of being designed to improve the intercity accessibility of passengers rather than freight [3,21]. The dominant role of HSR in facilitating the urban innovation level is ascribable to the increased intercity accessibility, the notion that to what extent the transport systems make it possible for individuals to access destinations by transport modes across cities [22,23].

Firstly, the intercity accessibility improved by HSR fosters more links of research collaboration. The high-frequency services of HSR increase the searching and matching efficiency and alleviate labor market segmentation [24], which renders research collaborations more likely to happen. Moreover, HSR promotes the efficiency of innovation resource allocation, matching resources on a larger scale [25]. Thus, the innovation level of cities can be enhanced by the integration of the labor market and better matching quality.

Secondly, the intercity accessibility enhanced by HSR promotes the quality of research collaboration. HSR increases individual mobility, facilitating knowledge exchange by more chances of face-to-face communication. Despite the fact that emerging information and communication technologies (ICT) have evolved the way people interact, face-to-face communication still plays an irreplaceable role in knowledge exchange. An underlying reason for this is that knowledge is known at least as two types: explicit (or codified) and tacit. The former is characterized by being coded, while the latter is the opposite. Tacit knowledge is endogenous in individuals, so collocated synchronous interaction is almost a necessity in observing, imitating, practicing, and learning [26]. Thus, intercity accessibility improves face-to-face communication and helps innovators grasp tacit knowledge.

Thirdly, the improved intercity accessibility brought by the HSR network makes it possible for individuals or organizations to reach a larger range within a certain time for innovation purposes. An ever more enormous accessible spatial scope offers more feasibility and convenience for the production, diffusion, and deployment of knowledge, and therefore promotes innovation through embeddedness in the network. Chen and Vickerman (2017) proposed that HSR constructions manifest a series of advantages, such as increasing accessibility and extending the rail network [27]. Not only has HSR opened up a larger market for firms in the city but also more competition. It is believed that competing interaction serves as an essential condition for industrial evolution and clustered innovation [28]. Cortinovis and Van Oort (2019) also agreed that network relations are a constructive foundation for R&D spillovers and that collaboration on patents is a representative vector of technological diffusion [29].

Some empirical results shed light on the effect of HSR facilities on the urban innovation level. Specifically, evidence from Jiang et al. (2017) supported that HSR connections yield a significant and positive impact on R&D collaboration between cities [8]. Wang and Cai (2020) also implied that the HSR establishment will promote research collaboration by 2–3% significantly, with a continuum of enhancement year after year [24]. Notably, scholars also mentioned that there exists a geographical boundary of the HSR impact on innovation through improved accessibility. Wang and Cai (2020) estimated that the cut-off point of the HSR construction's impact on innovation is about 300 km, with evidence from invention patents [24]. Yang et al. (2021) noted that the innovation spillover range from the innovation center is around 300 km, which means accessibility improved by transport only affects the innovation spillover in a limited space [30].

2.2. The Mechanism of the Impact of Intercity Accessibility Brought by HSR on the Urban Innovation Level

Factors found to be influencing urban innovation levels in the previous studies are, for instance, human capital [31], infrastructure construction [32], social capital [33], industrial characteristics [34], research and development investment [35], diversity [36], economic development level, and so forth. Some studies suggest that human capital and financial input are among the most important factors for innovation level. Lao et al. (2021) found that human capital improves the level of innovation with the largest scale effects among a series of considerations [31]. Mattessich and Monsey (1992) summarized that financial and human "input" are necessary resources that influence successful collaboration [37].

We hereby propose two plausible mechanisms through which HSR promotes urban innovation levels with better intercity accessibility: enhanced human capital and greater opportunities for science and technology funds.

First, regarding human capital, HSR promotes individual mobility with high speed and convenience, which provides a foundation for more attractive location conditions of cities. Lin (2017) has found that the HSR connection increases passenger flows [13], especially of highly qualified laborers or higher-education students. They are important carriers of innovation because they exert a fairly important role in knowledge spillover [1]. Knowledge spillover is recognized to be an essential engine for innovation [25].

On the one hand, with respect to highly qualified labor, Malecki (1997) made an early and seminal indication that skilled laborers figure prominently as a major channel in the knowledge transfer and spillover [38]. Audretsch and Feldman (2004) concluded that the knowledge spillovers are realized as skilled laborers move between jobs, equipped with accumulated skills and know-how [39]. Dong, Zheng, and Kahn (2020) also lent support to the point that HSR construction decreases the travel time across cities, with an operating speed about twice that of the past train, thereby boosting face-to-face interactions among highly skilled workers [40].

On the other hand, concerning higher-education students, Acs, Anselin, and Varga (2002) showed that research universities serve as a platform that facilitates knowledge spillovers by recruiting and retaining talent to the region, transferring and industrializing scientific and technological outcomes through local interactions and connections, referring students to industry, and offering a base for interactions among individuals, firms, and government agencies [41]. Consequently, one of the mechanisms by which HSR positively impacts creative activities is by enhancing the diffusion of ideas and the spillover effects of knowledge achieved by increased individual mobility.

Significantly, knowledge spillover also features localization and decay effects. Murata et al. (2014) confirmed the existence of localized knowledge spillovers with solid evidence from patent citations and estimated that the majority of technology patents are localized at least once within 200 km, albeit there is no universally accepted recognition of an exact geographic distance [42]. It should be noticed that numerous papers suggest that location and proximity count in knowledge spillovers; this is why spillovers have a decay effect as they move across geographic space [39].

Second, we focus on science and technology funds, which have received scant attention up to now. The flow and movement of capital can be strengthened when the highly educated or skilled workers are mobile. However, there remains a paucity of evidence on the quantitative analysis of better accessibility to science and technology funds brought by HSR. Nevertheless, some studies found a positive impact of transport infrastructure on capital flow. With insights on international flights from a global view, Campante (2016) suggested that airplanes promote face-to-face connections, smoothing the path for business links as well as fostering the movement of capital and increasing foreign direct investment (FDI) [43]. Concerning the HSR impact on funds or investment, Lin et al. (2019) found that HSR could promote interregional investment flow, especially in industries that are more likely to involve face-to-face interactions and onsite administration [44]. However, how the accessibility to science and technology fund impacts the innovation level of cities are less considered in the literature, which demands further investigation.

Above all, the impact of the intercity accessibility brought by HSR on the urban innovation level can be explained by various factors. The increasing human capital mobility has been accepted by most scholars, and greater opportunities for science and technology funds has not been considered by many studies yet. This research explained the impact through enhanced human capital mobility and greater opportunities for science and technology funds. Additionally, past studies on the impact of new transport infrastructure on local economy suggest three likely outcomes: (1) constant positive effects, (2) differential effects, and (3) straw effects [45]. Regarding the impact of HSR on innovation, it is also necessary to compare the various benefits of cities with different innovation capacities.

3. Data and Methodology

3.1. Research Design and Variables

We first investigate the impact of HSR facilities on the innovation levels of cities in megacity regions in China. The research mainly includes two parts, namely benchmark regression and mechanism analysis (Figure 2). The main explanatory variable is intercity accessibility, which refers to cities that could be reached within 2, 4, and 6 h by HSR. Second, we further conducted mechanism analysis through human capital mobility and science and technology fund mobility.

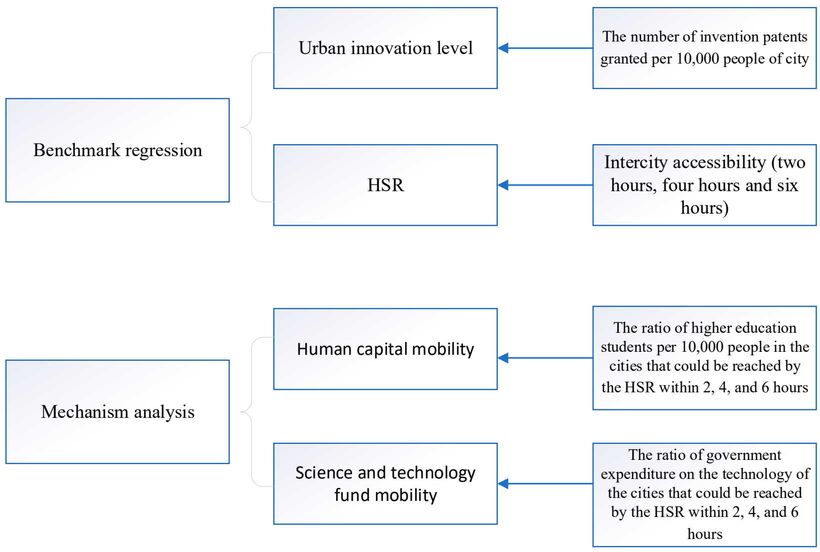

Figure 2. Research steps and main variables.

The dependent variable is Ing_{it}, measured by the number of invention patents granted per 10,000 people of city i. It is employed to capture the innovation level for the following reasons. Firstly, patents are endowed with fresh ideas, cutting-edge technology, and new products, whether tangible or intangible. The literature has been fairly extensive suggesting or using patents as a good indicator of the output of inventive activity [7,26,39,46]. Moreover, patent databases make it possible to compare innovation activities in different places in various periods. Secondly, an invention patent is the only one that requires rigorous substantive examination based on China's patent law within patent types in China (SIPO). Thus, an invention patent is regarded to be more innovative to some extent.

We proposed a series of major explanatory variables as follows. Intercity accessibility is measured by the number of cities accessible within 2, 4, and 6 h by HSR. We calculate the number of cities within 2 h that the HSR can connect, because 2 h is a bearable time for people to commute between cities for work [47]. The number of cities within 4 h that the HSR can connect means people can visit the city and return to their own city within one day, which is an essential cut-off point for a comfortable day trip [48]. Finally, since the longest hours from one city to the other within the three megacity regions is around seven hours, we choose the number of cities within 6 h that HSR can connect to investigate the impact of cities on other cities within the three respective megacity regions.

The number of cities to which the HSR can connect within 2, 4, and 6 h are calculated in the following ways. We first obtain the minimal intercity commuting time within the three urban agglomerations from 2009 to 2019 through the website of China Railway "12306". It should be noticed that the HSR commuting time is merely available for the latest 15 days, and there is no official access to historical commuting time, unless we keep checking every day. Thus, it is necessary to assume that once an HSR station starts operation, the commuting time from there to other HSR stations stays unchanged. Then, by tracing the annual openings of the HSR stations in these cities from the China Railway website, we identify the minimal intercity commuting time by HSR over the years. Finally, we are able to derive the number of cities accessible within 2, 4, and 6 h by HSR.

As for explanatory variables in the mechanism analysis, we adopt the intercity accessibility to human capital and scientific research funds by HSR. As the number of employees conducting scientific research in enterprises at the city level is unavailable, human capital is represented by higher-education students per 10,000 people. The variable of higher-education students per 10,000 people is indicative of potential talents in these cities conducting scientific research [48]. We calculate the ratio of higher-education students per 10,000 people in the cities that could be reached by HSR within 2, 4, and 6 h to the number of that in the region. Scientific research funds are indicated by the government expenditure on science and technology [31]. By the same token, we calculate the ratio of government expenditure on the technology of the cities that could be reached by HSR within 2, 4, and 6 h to the number of that in the region.

As for control variables, innovation and the local economic development level are closely related. Therefore, we adopt secondary industry as a percentage of GDP to capture industrial structure. We use the total registered population at year end as a control for the size of the city [24]. The level of the opening up of cities is controlled by the proportion of foreign investment in GDP [49,50]. Finally, as a highway can also impact the innovation level of a city, we also include highway ridership to control the population mobility, as it is also one of the ways that people interact and communicate face-to-face [40].

The dependent variables (from 2011 to 2020) are obtained from the Chinese Research Data Services (CNRDS) Platform. The control variables are gleaned from the China City Statistical Year Books in China. All the control variables in the empirical results are lagged for two years (from 2009 to 2018), as the impact of HSR facilities on innovation activities has a hysteresis effect. Meanwhile, lagging also serves to avoid the simultaneity bias [30]. Below, Table 1 demonstrates the variable meaning and summary statistics.

Table 1. Descriptive statistics of the model variables.

Variables	Definition	N	Mean	Sd	Min	Max	Sources
Invg *	Invention patents granted per 10,000 people	730	0.805	0.871	0.006	4.214	Chinese Research Data Services (CNRDS) Platform
Umg *	Utility models granted per 10,000 people	730	1.803	1.133	0.082	5.341	Chinese Research Data Services (CNRDS) Platform
City_within2	Cities connected within 2 h (by HSR)	730	6.275	6.965	0	27	12306 website
City_within4	Cities connected within 4 h (by HSR)	730	10.130	11.350	0	37	12307 website
City_within6	Cities connected within 6 h (by HSR)	730	11.290	12.630	0	37	12308 website
Within2_stu	Ratio of higher education students connected within 2 h (by HSR)	730	0.280	0.280	0	0.899	China City Statistical Year Books in China
Within4_stu	Ratio of higher education students connected within 4 h (by HSR)	730	0.447	0.366	0	0.968	China City Statistical Year Books in China
Within6_stu	Ratio of higher-education students connected within 6 h (by HSR)	730	0.499	0.394	0	0.986	China City Statistical Year Books in China
Within2_tech	Ratio of technological funds connected within 2 h (by HSR)	730	0.323	0.344	0	0.975	China City Statistical Year Books in China
Within4_tech	Ratio of technological funds connected within 4 h (by HSR)	730	0.505	0.411	0	0.987	China City Statistical Year Books in China
Within6_tech	Ratio of technological funds connected within 6 h (by HSR)	730	0.537	0.428	0	0.99	China City Statistical Year Books in China
Sec *	Secondary industry as a percentage of GDP	730	3.880	0.180	2.977	4.327	China City Statistical Year Books in China
Pop *	Total registered population	730	6.103	0.602	4.315	7.288	China City Statistical Year Books in China
Roadvol *	Highway passenger volume	730	8.921	0.955	6.874	12.18	China City Statistical Year Books in China
FDI *	Foreign direct investment	730	1.202	0.960	0.04	10.27	China City Statistical Year Books in China
Slope	Slope = elevation difference/ horizontal distance	730	2.046	1.928	0.0111	8.429	Peking University Geographical Platform
Plain	The percentage of plain area under 200 mabove the sea in the city level	730	0.773	0.263	0.0004	1	Peking University Geographical Platform

* represents logarithmization: the transformation ln(x+1) of each highlighted variable is made.

3.2. Model

According to the literature review, HSR facilities have contributed significantly to various aspects of regional economic development. It is emphasized that the first and foremost impact is accessibility. In light of this viewpoint, we construct the explanatory variables to reflect intercity accessibility in terms of commuting time. Formulations (1)–(3) present our benchmark fixed effect regression considering the instrumental variable model:

$$Ing_{it} = \beta_0 + \beta_1 City\_within2_{i,t-2} + \beta_j \sum X_{jit} + u_i + \varepsilon_{it} \quad (1)$$

$$Ing_{it} = \beta_0 + \beta_1 City\_within4_{i,t-2} + \beta_j \sum X_{jit} + u_i + \varepsilon_{it} \quad (2)$$

$$Ing_{it} = \beta_0 + \beta_1 City\_within6_{i,t-2} + \beta_j \sum X_{jit} + u_i + \varepsilon_{it} \quad (3)$$

In Formulations (1)–(3), $City\_within2_{it}$ represents the number of cities that could be reached by HSR within 2 h of city i in period $t-2$ (lagged for two years). The interpretations for $City\_within4_{it}$ and $City\_within6_{it}$ are likewise. Ing_{it} denotes the number of invention patents granted in city i in year t. X_{jit} refers to the j control variables adopted. The municipal effect μ_i indicates all the time-invariant differences across cities. ε_{it} is the random error term.

To arrive at consistent estimations, annual variations in HSR facilities in each city in the region are required to be uncorrelated with other city-specific shocks. Yet, this assumption may not hold, since cities with more patents are typically correlated with greater economic status and more favorable political characteristics of a location, which may witness relatively more of the HSR facilities. Therefore, we utilize variation in the HSR facilities induced by differences between slope and plain to obtain instrumental variable estimates. They are both geographic characteristics that are associated with HSR facilities and uncorrelated to the urban innovation level.

Slope refers to an urban slope index indicative of the terrain features of the city. Cities with higher slope indexes are confronted with more challenges in constructing transport infrastructure, such as HSR. We employ the digital elevation model (DEM) raster data of all the selected cities in three regions to extract the average slope of the sample cities (slope = elevation difference/horizontal distance) [51].

In addition, we also adopt plain as another instrumental variable, an elevation measured by the percentage of plain area under 200 m above the sea in the municipality [11]. Cities of lower elevation are easier to construct HSR. As the instrumental variables are time-invariant, we exploit the interactions of slope and plain with year variables as instrumental variables [25,44–46,52–54]. The Hansen J and identification tests are conducted in the instrumental variable method.

The mechanisms of how HSR facilities affect the innovation level of a city are identified by two channels: more convenient face-to-face interaction between highly educated people and more effective access to fiscal funds for science and technology.

Formulations (4)–(6) and (7)–(9) show our proposed channels:

$$Ing_{it} = \beta_0 + \beta_1 Within2\_stu_{i,t-2} + \beta_j \sum X_{jit} + u_i + \varepsilon_{it} \tag{4}$$

$$Ing_{it} = \beta_0 + \beta_1 Within4\_stu_{i,t-2} + \beta_j \sum X_{jit} + u_i + \varepsilon_{it} \tag{5}$$

$$Ing_{it} = \beta_0 + \beta_1 Within6\_stu_{i,t-2} + \beta_j \sum X_{jit} + u_i + \varepsilon_{it} \tag{6}$$

$$Ing_{it} = \beta_0 + \beta_1 Within2\_tech_{i,t-2} + \beta_j \sum X_{jit} + u_i + \varepsilon_{it} \tag{7}$$

$$Ing_{it} = \beta_0 + \beta_1 Within4\_tech_{i,t-2} + \beta_j \sum X_{jit} + u_i + \varepsilon_{it} \tag{8}$$

$$Ing_{it} = \beta_0 + \beta_1 Within6\_tech_{i,t-2} + \beta_j \sum X_{jit} + u_i + \varepsilon_{it} \tag{9}$$

where $Within2\_stu_{it}$ stands for the ratio of the number of higher-education students per 10,000 people of the cities that could be reached by HSR within 2 h of city i to the number of those in the region in period $t-2$. We handle $Within4\_stu_{it}$ and $Within6\_stu_{it}$ similarly.

$Within2\_tech_{it}$ is the ratio of the government expenditure on the technology of the cities that could be reached by HSR within 2 h of city i to the number of those in the region in period $t-2$. Incidentally, $Within4\_tech_{it}$ and $Within6\_tech_{it}$ represent the same meaning.

4. Empirical Result

4.1. Basic Result

In this section, we aim to explore whether HSR facilities have an impact on urban innovation levels through facilitating transportation accessibility. First, we use the fixed effects model, taking account of two instrumental variables. Table 2 demonstrates that the number of cities that can be reached within 2, 4, and 6 h by HSR are all significantly positively related to the invention patents granted. In columns (1) to (3), we first estimate the standalone effect of $City\_within2$, $City\_within4$, and $City\_within6$ on Ing_{it}. Column (1) shows that the number of cities that can be reached within 2 h by HSR is significantly positively related to invention patents granted. In columns (2) and (3), the number of cities reachable within 4 and 6 h are also significantly positively associated with invention patents granted, but with a diminishing magnitude of effect. In columns (4) to (6), we include the control variables. Now, when the number of cities that can be reached within 2, 4, and 6 h by HSR increases by one unit, the invention patents granted per 10,000 people of this city will increase by an average of 5.8%, 3.5%, and 3.1%, respectively, holding others constant. Obviously, there is a diminishing effect of HSR facilities on invention patents granted with the increasing commuting time. Above all, we conclude that this analysis supports our assertion that HSR facilities increase intercity accessibility and exert a positive impact on the innovation level with a decay effect. In Table 2, IV diagnostics suggest that plain and slope are not weakly identified or under-identified. The Hansen J statistic suggests that both instrumental variables are orthogonal to the structural equation error term.

Table 2. Estimated results of the impact of the number of cities accessible within 2, 4, and 6 h by HSR on invention patents granted.

Variables	(1) Invg	(2) Invg	(3) Invg	(4) Invg	(5) Invg	(6) Invg
City_within2	0.070 ***			0.058 ***		
	(0.004)			(0.005)		
City_within4		0.040 ***			0.035 ***	
		(0.002)			(0.003)	
City_within6			0.036 ***			0.031 ***
			(0.002)			(0.002)
Control variables				Yes	Yes	Yes
Observations	730	730	730	730	730	730
R^2	0.210	0.266	0.274	0.341	0.371	0.384
Under-identification test	232.1 ***	249.0 ***	249.9 ***	91.7 ***	97.7 ***	99.6 ***
Weak identification test	287.4	335.6	340.4	95.6	110.9	113.9
Hansen J statistic	0.334	1.211	1.647	0.154	0.605	0.868

Robust standard errors in parentheses; *** $p < 0.01$; clustered at city levels.

4.2. Mechanism

In this section, we explore the mechanisms through which the improved intercity accessibility brought by HSR improves urban innovation levels. We propose two channels: more convenient face-to-face interaction between highly educated people and more effective access to fiscal funds for science and technology.

4.2.1. More Convenient Face-to-Face Interaction

HSR improves accessibility between cities, accelerates face-to-face communication among people, and encourages communication of higher-education students between universities or scientific research institutions, which is conducive to knowledge spillovers and encourages innovative activities.

We estimate regressions of $Within2\_stu$, $Within4\_stu$, and $Within6\_stu$ on Ing_{it}, respectively. In Table 3, columns (1)–(3) show that when the ratio of accessible higher-education students by HSR within 2, 4, and 6 h goes up by one unit, the invention patents granted to the city will increase significantly by an average of 184.8%, 96.4%, and 82.2% accordingly. The decreasing trend of coefficients lends further support to our basic result that there is a diminishing effect as the cost of commuting time increases.

Table 3. IV model results explaining the impact of the university student proportion of the cities to that of the region by HSR within 2, 4, and 6 h on invention patents granted.

Variables	(1) Invg	(2) Invg	(3) Invg
Within2_stu	1.848 ***		
	(0.184)		
Within4_stu		0.964 ***	
		(0.082)	
Within6_stu			0.822 ***
			(0.069)
Control varibles	Yes	Yes	Yes
Observations	730	730	730
R^2	0.138	0.302	0.323
Under-identification test	80.3 ***	117.6 ***	128.7 ***
Weak identification test	71.0	153.8	189.4
Hansen J statistic	0.005	0.262	0.226

Robust standard errors in parentheses; *** $p < 0.01$; clustered at city levels.

4.2.2. More Effective Accessibility to Funds on Technology

Fiscal funds for science and technology are a usual indicator of input on inventive activities [39,47]. We probe into the question of whether the transportation convenience brought by the HSR will promote the spillover effect of technology funds on patent innovation regionally. For this purpose, we follow the model in Table 3 and replace the main explanatory variables with the ratio of accessible fiscal funds for science and technology within 2, 4, and 6, that is, $Within2\_tech$, $Within4\_tech$, and $Within6\_tech$. Columns (1)–(3) in Table 4 exhibit that when the ratio of accessible technology funds within 2, 4, and 6 h by HSR goes up by one unit, the invention patents granted by the city will significantly increase by an average of 151.1%, 85.5%, and 76.7%, accordingly. Consistent with our previous findings, there is a diminishing spillover effect of scientific funds with the increasing commuting time.

Table 4. IV model results explaining the impact of the proportion of government technology expenditure of the cities to that of the region by HSR rail within 2, 4, and 6 h on invention patents granted.

Variables	(1) Invg	(2) Invg	(3) Invg
Within2_tech	1.511 ***		
	(0.158)		
Within4_tech		0.855 ***	
		(0.076)	
Within6_tech			0.767 ***
			(0.067)
Control variables	Yes	Yes	Yes
Observations	730	730	730
R^2	0.081	0.257	0.284
Under-identification test	73.3 ***	108.2 ***	116.3 ***
Weak identification test	59.4	134.5	158.5
Hansen J statistic	0.195	0.351	0.258

Robust standard errors in parentheses; *** $p < 0.01$; clustered at city levels.

Overall, the results in Tables 2–4 support our conjectures that HSR facilities boost city innovation levels by improving intercity accessibility, namely facilitating talent interaction and the accessibility to technology capital investment. Compared with the coefficient of the higher-education student ratio and the technology fund ratio in Tables 3 and 4, we find that talent interaction exerts a larger magnitude of effect on the innovation level of a city than technology capital investment.

4.3. Heterogeneous Analysis

It is a natural thought to divide the 73 cities into three regions to conduct the heterogeneous test. However, as the Beijing-Tianjin-Hebei region only includes 12 cities, the sample is not enough for panel regression. Instead, we study the heterogeneous effect of HSR facilities on innovation based on their initial innovative levels and whether they possess first-class universities.

4.3.1. City Innovation Level Heterogeneous Effects

As for the innovative level, we divide the 73 cities into two groups and define the top 30% cities as highly innovative cities and the rest as less innovative, based on the number of invention patents granted in 2009, the year of initial observation. In Tables 5 and 6, for both groups, the ratio of accessible higher-education students and the ratio of accessible fiscal funds for science and technology by HSR within 2, 4, and 6 h are all significantly positively related to invention patents granted. Still, the former coefficients are slightly larger than the latter and there is a diminishing effect as commuting time increases. However, not all of the coefficients on the considered explanatory variables are statistically significant for highly innovative cities.

Table 5. The heterogeneous impact of city level on invention patents granted: university student ratio (top 30% as highly innovative cities).

	Highly Innovative			Less Innovative		
Variables	**(1) Invg**	**(2) Invg**	**(3) Invg**	**(4) Invg**	**(5) Invg**	**(6) Invg**
Within2_stu	2.430 ***			1.812 ***		
	(0.470)			(0.214)		
Within4_stu		1.695 ***			0.869 ***	
		(0.274)			(0.085)	
Within6_stu			1.571 ***			0.722 ***
			(0.239)			(0.069)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.321	0.453	0.505	−0.165	0.143	0.181
Observations	220	220	220	510	510	510
Under-identification test	25.3 ***	38.4 ***	41.6 ***	60.3 ***	91.4 ***	101.9 ***
Weak identification test	18.2	31.1	35.6	51.3	108.6	139.3
Hansen J statistic	1.305	0.291	0.150	1.076	1.114	0.782

Robust standard errors in parentheses; *** $p < 0.01$; clustered at city levels.

Table 6. The heterogeneous impact of city level on invention patents granted: government scientific funds (top 30% as highly innovative cities).

	Highly Innovative			Less Innovative		
Variables	**(1) Invg**	**(2) Invg**	**(3) Invg**	**(4) Invg**	**(5) Invg**	**(6) Invg**
Within2_tech	1.913 ***			1.457 ***		
	(0.326)			(0.187)		
Within4_tech		1.478 ***			0.753 ***	
		(0.231)			(0.077)	
Within6_tech			1.415 ***			0.665 ***
			(0.215)			(0.066)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.751	−0.239	0.101	−0.658	0.054	0.116
Observations	220	220	220	510	510	510
Under-identification test	28.6 ***	34.9 ***	35.9 ***	53.1 ***	86.8 ***	94.4 ***
Weak identification test	20.4	27.3	29.2	40.4	100.6	123.3
Hansen J statistic	0.438	0.127	0.071	1.286	1.112	0.778

Robust standard errors in parentheses; *** $p < 0.01$; clustered at city levels.

The possible reasons for the results are as follows. After the opening of HSR in the region, knowledgeable talents and scientific and technological investments of the highly innovative cities overflow to the less innovative via HSR. Similar to the straw effect of HSR on local economy development, the more innovative the cities the more the increasing innovation level could be ascribed to more talent exchanges and capital overflow brought by HSR facilities.

4.3.2. Double First-Class University Heterogeneous Effects

Besides the innovation level of a city, the first-class universities feature prominent scientific research and innovation capabilities, the spillover of which can effectively enhance the urban innovation level. The Double First-Class University Plan (*Shuangyilou*) is a Chinese government program aiming at comprehensively developing a group of elite Chinese universities and individual university departments into world-class universities and disciplines by the end of 2050. The double first-class universities can represent the high-level universities in China. To understand the heterogeneous impacts of HSR facilities on the innovative levels of cities with and without double first-class, we examine the mechanism tests separately. In Tables 7 and 8, both groups of cities experience positive and significant decay effects of HSR facilities on urban innovation. The coefficients in the model with double first-class universities are higher compared with those without. It means that cities with double first-class universities benefit more from HSR compared with those without first-class universities. The explanation is consistent with the straw effect of HSR on urban innovation.

Table 7. The heterogeneous impact of double first-class university on invention patents granted: university student ratio.

	Cities with Double First-Class Universities			Cities without Double First-Class Universities		
Variables	**(1) Invg**	**(2) Invg**	**(3) Invg**	**(4) Invg**	**(5) Invg**	**(6) Invg**
Within2_stu	3.074 *** (1.015)			1.788 *** (0.197)		
Within4_stu		2.365 *** (0.692)			0.889 *** (0.083)	
Within6_stu			2.185 *** (0.599)			0.746 *** (0.068)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.111	0.289	0.378	0.057	0.284	0.311
Observations	120	120	120	610	610	610
Under-identification test	14.3 ***	18.8 ***	20.1 ***	67.7 ***	101.7 ***	112.9 ***
Weak identification test	9.7	17.2	22.3	58.3	126.0	160.7
Hansen J statistic	0.739	0.626	0.664	0.0235	0.155	0.105

Robust standard errors in parentheses; *** $p < 0.01$; clustered at city levels.

Table 8. The heterogeneous impact of double first-class universities on invention patents granted: government scientific funds.

	Cities with Double First-Class Universities			Cities without Double First-Class Universities		
Variables	**(1) Invg**	**(2) Invg**	**(3) Invg**	**(4) Invg**	**(5) Invg**	**(6) Invg**
Within2_stu	2.477 *** (0.818)			1.470 *** (0.174)		
Within4_stu		1.927 *** (0.573)			0.791 *** (0.077)	
Within6_stu			1.857 *** (0.545)			0.701 *** (0.066)
Observations	120	120	120	610	610	610
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.155	0.333	0.364	−0.022	0.235	0.270
Under-identification test	10.6 ***	13.5 ***	13.8 ***	59.1 ***	92.7 ***	101.1 ***
Weak identification test	7.7	12.6	13.4	46.6	111.5	135.7
Hansen J statistic	0.459	0.521	0.533	0.151	0.176	0.103

Robust standard errors in parentheses; *** $p < 0.01$; clustered at city levels.

4.4. Robustness Test

4.4.1. Explanatory Variables of the Baseline Model Lagged for Three Years

In this section, we conduct a robustness check for the baseline model, where all the explanatory variables are lagged for two years mainly due to the hysteresis effect. Now, we investigate whether the results are still statistically positive when lagging for three years. Not surprisingly, Table 9 demonstrates that the number of cities that can be reached within 2, 4, and 6 h by HSR are still significantly positively related to the invention patents granted. The coefficients are 6.2%, 3.8%, and 3.4%. At the same time, there exists a decay effect as commuting time increases. These results further confirm and reinforce the robustness of previously drawn conclusions.

Table 9. The robustness test of the baseline model when all explanatory variables lagged for three years.

Variables	**(1) Invg**	**(2) Invg**	**(3) Invg**
City_within2	0.062 *** (0.005)		
City_within4		0.038 *** (0.003)	
City_within6			0.034 *** (0.003)
Control variables	Yes	Yes	Yes
R^2	0.489	0.502	0.507
Observations	657	657	657
Under-identification test	84.5 ***	87.8 ***	89.0 ***
Weak identification test	84.6	93.7	95.7
Hansen J statistic	0.789	1.879	2.491

Robust standard errors in parentheses; *** $p < 0.01$; clustered at city levels.

4.4.2. Replacing Explained Variable

The patent system in China can be categorized into three types: invention patent, utility model patent, and design patent. A utility model patent is considered to be less inventive than an invention patent but features more innovative activities than a design patent. Therefore, we replace the invention patents granted with the utility model patents granted and lag the explanatory variables for two years to verify the robustness of the conclusion in this paper. In Table 10, we can see that the sign and significance of the coefficients of the three columns are all preserved.

Table 10. The robustness test of the baseline model when dependent variable replaced by utility model patent granted.

Variables	(1) Umg	(2) Umg	(3) Umg
City_within2	0.128 ***		
	(0.010)		
City_within4		0.078 ***	
		(0.006)	
City_within6			0.069 ***
			(0.005)
Observations	730	730	730
R^2	0.013	0.036	0.052
Control variables	Yes	Yes	Yes
Under-identification test	91.7 **	97.7 ***	99.7 ***
Weak identification test	95.6	110.9	113.9
Hansen J statistic	0.001	0.183	0.340

Robust standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$; clustered at city levels.

4.4.3. Excluding the Impact of COVID-19

Another condition we need to consider is COVID-19, which influenced human mobility by HSR in 2020. We excluded the 2020 year in the model, and we find similar results (See Table 11), which indicates that the result about the impact of HSR facilities on urban innovation levels is robust.

Table 11. Estimated results of the impact of the number of cities accessible within 2, 4, and 6 h by HSR on inventions patent granted without COVID-19 period.

Variables	(1) Invg	(2) Invg	(3) Invg	(4) Invg	(5) Invg	(6) Invg
City_within2	0.058 ***			0.053 ***		
	(0.003)			(0.005)		
City_within4		0.035 ***			0.032 ***	
		(0.002)			(0.003)	
City_within6			0.031 ***			0.029 ***
			(0.002)			(0.002)
Control variables				Yes	Yes	Yes
Observations	730	730	730	730	730	730
R^2	0.183	0.236	0.234	0.263	0.299	0.302
Under-identification test	192.7 ***	203.7 ***	204.9 ***	84.5 ***	87.8 ***	89.0 ***
Weak identification test	220.7	244.3	247.6	84.6	93.7	95.7
Hansen J statistic	0.431	1.746	2.406	0.324	1.226	1.748

Robust standard errors in parentheses; *** $p < 0.01$; clustered at city levels.

5. Conclusions

We contribute to the literature by highlighting the spatial attenuation impact of HSR on the urban innovation level as well as the underlying mechanisms. Compared with previous research, the spatial attenuation effect is better examined by adopting intercity accessibility variables [30,55]. We enrich the literature by providing evidence on the effect of science and technology investment, which is less discussed in the previous research [24,30]. Notably, the contribution of talent interaction brought by intercity accessibility to the urban innovation level is greater than the technology funds.

The mechanisms through which HSR facilities affect innovation can be explained by the fact that HSR enhances regional intercity accessibility. Firstly, this would facilitate knowledge spillover because more research collaborations are fostered and reinforced by reducing the cost of face-to-face interaction among higher-education students. Secondly, it would also accelerate the movement of scientific funds, indicated by connecting more cities with considerable government expenditure on science and technology. Both positive effects of the two mechanisms dissipated with increasing commuting time. Our findings on human capital mobility are similar to the evidence found in previous studies [40]. We enrich the literature by providing evidence on the effect of science and technology investment. Notably, the contribution of talent interaction brought by intercity accessibility to the urban innovation level is greater than the technology funds.

Further, we study the heterogeneous effect of HSR facilities on innovation levels in cities with different innovative capacities and with various levels of universities [19,48]. We find that HSR facilities benefit the more innovative cities and cities with double first-class universities more. It shows that HSR promotes the cities with more resources, which is consistent with the straw effect of HSR on the local economy.

The research findings provide several policy implications. First, the impact of HSR on the urban innovation level is most substantial within 2 h, which is consistent with the previous finding of the influential scope of metropolitan regions [56]. Therefore, policymakers should consider improving the intercity accessibility within 2 h of travel time to increase the impact of metropolitan regions. Second, as talent interaction exerts a larger effect on urban innovation levels than technology investment opportunities, it is essential to create conditions for talent interactions to improve urban innovation levels. Third, as the urban innovation level of cities benefits differently from HSR, policymakers should consider the cost and benefits of HSR facilities in various types of cities based on intercity accessibility changes in megacity regions. Finally, as HSR intercity accessibility has improved in the past decade in China, we can observe the positive impact of sustainable transportation accessibility improvement on urban innovation. Policymakers should also pay attention to the impact of external shocks on transportation, such as the COVID-19 epidemic.

Our research studies the impact of HSR on the urban innovation level based on the change in intercity accessibility among cities in megacity regions. Moreover, we uncover the mechanism underlying how HSR affects innovation, that is, the movement and interaction of human capital, as well as the better accessibility to technology funds. The impact of HSR on the urban innovation level can be complex, and we avoid the endogenous problem by adopting the instrumental variable method. The limitation of this research is we only focus on megacity regions in China. Future research can compare the impact of HSR facilities on urban innovation levels in large regions in both developing and developed countries. Additionally, the impact of more transportation modes on urban innovation levels can be considered, such as airway or seaway. Another limitation of this research is the innovation level of some cities can be higher because the patents generated by firms tend to register in cities where firm headquarters are located. Future research can recalculate urban innovation levels when more detailed information about patents is available.

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References

1. Chen, G.; Silva, J.D.A.E. Methods and Models Regional Impacts of High-Speed Rail: A Review of Methods and Models. *Transport. Lett.* **2013**, *5*, 131–143. [CrossRef]
2. Pol, P.M.J. The Economic Impact of the High-Speed Train on Urban Regions. *ERSA Conf.* **2003**, 1–20.
3. Komikado, H.; Morikawa, S.; Bhatt, A.; Kato, H. High-Speed Rail, Inter-Regional Accessibility, and Regional Innovation: Evidence from Japan. *Technol. Forecast. Soc. Chang.* **2021**, *167*, 120697. [CrossRef]
4. Hasan, I.; Tucci, C.L. The Innovation-Economic Growth Nexus: Global Evidence. *Res. Policy* **2010**, *39*, 1264–1276. [CrossRef]
5. Elsner, W.; Heinrich, T.; Schwardt, H. Networks and Innovation—The Networked Firm, Innovation Systems, and Varieties of Capitalism. *Microecon. Complex Econ.* **2015**, *Vol.*, 473–498. [CrossRef]
6. Wang, J.; Liu, N.; Ruan, Y. Influence Factors of Spatial Distribution of Urban Innovation Activities Based on Ensemble Learning: A Case Study in Hangzhou, China. *Sustainability* **2020**, *12*, 1016. [CrossRef]
7. Florida, R.; Adler, P.; Mellander, C. The City as Innovation Machine. *Transit. Reg. Econ. Dev.* **2018**, *51*, 151–170. [CrossRef]
8. Jiang, S.Q.; Shi, A.; Peng, Z.H.; Li, X. Major Factors Affecting Cross-City R&D Collaborations in China: Evidence from Cross-Sectional Co-Patent Data between 224 Cities. *Scientometrics* **2017**, *111*, 1251–1266. [CrossRef]
9. Scherngell, T.; Hu, Y. Collaborative Knowledge Production in China: Regional Evidence from a Gravity Model Approach. *Reg. Stud.* **2011**, *45*, 755–772. [CrossRef]
10. Ma, H.; Fang, C.; Pang, B.; Li, G. The Effect of Geographical Proximity on Scientific Cooperation among Chinese Cities from 1990 to 2010. *PLoS ONE* **2014**, *9*, e111705. [CrossRef]
11. Lu, H.; Zhao, P.; Hu, H.; Zeng, L.; Wu, K.S.; Lv, D. Transport Infrastructure and Urban-Rural Income Disparity: A Municipal-Level Analysis in China. *J. Transp. Geogr.* **2022**, *99*, 103292. [CrossRef]
12. Xu, W.A.; Huang, Y. The Correlation between HSR Construction and Economic Development—Empirical Study of Chinese Cities. *Transp. Res. Part A* **2019**, *126*, 24–36. [CrossRef]
13. Lin, Y. Travel Costs and Urban Specialization Patterns: Evidence from China's High Speed Railway System. *J. Urban Econ.* **2017**, *98*, 98–123. [CrossRef]
14. Dong, X. High-Speed Railway and Urban Sectoral Employment in China. *Transp. Res. Part A Policy Pract.* **2018**, *116*, 603–621. [CrossRef]
15. Diao, M. Does Growth Follow the Rail? The Potential Impact of High-Speed Rail on the Economic Geography of China. *Transp. Res. Part A* **2020**, *113*, 279–290. [CrossRef]
16. Holl, A. Highways and Productivity in Manufacturing Firms. *J. Urban Econ.* **2016**, *93*, 131–151. [CrossRef]
17. Shen, Y.; Silva, J.d.A.; Martínez, L.M. HSR Station Location Choice and Its Local Land Use Impacts on Small Cities: A Case Study of Aveiro, Portugal. *Proc. Soc. Behav. Sci.* **2014**, *111*, 470–479. [CrossRef]
18. Hou, Y. Agglomeration Spillover, Accessibility by High-Speed Rail, and Urban Innovation in China: A Focus on the Electronic Information Industry. *Habitat Int.* **2022**, *126*, 102618. [CrossRef]
19. Tang, E. Study on Impact and Spatial Spillover Effect of Beijing Shanghai High Speed Rail on Urban Innovation Capability along the Line. *Areal Res. Dev.* **2021**, *40*, 57–63.
20. Lee, S.Y.; Florida, R.; Gates, G. Innovation, Human Capital, and Creativity. *Int. Rev. Public Adm.* **2010**, *14*, 13–24. [CrossRef]
21. Hiroyasu, I. *The Impact of the Opening of High-Speed Rail on Innovation*; RIETI: Tokyo, Japan, 2017.
22. Geurs, K.T.; van Wee, B. Accessibility Evaluation of Land-Use and Transport Strategies: Review and Research Directions. *J. Transp. Geogr.* **2004**, *12*, 127–140. [CrossRef]
23. Wang, Y.; Cao, G.; Yan, Y.; Wang, J. Does High-Speed Rail Stimulate Cross-City Technological Innovation Collaboration? Evidence from China. *Transp. Policy* **2022**, *116*, 119–131. [CrossRef]
24. Wang, J.; Cai, S. The Construction of High-Speed Railway and Urban Innovation Capacity: Based on the Perspective of Knowledge Spillover. *China Econ. Rev.* **2020**, *63*, 101539. [CrossRef]
25. Tang, C.; Guan, M.; Dou, J. Technology in Society Understanding the Impact of High Speed Railway on Urban Innovation Performance from the Perspective of Agglomeration Externalities and Network Externalities. *Technol. Soc.* **2021**, *67*, 101760. [CrossRef]
26. Olson, G.M.; Olson, J.S. Human–Computer Interaction Distance Matters. *Int. J. Hum. Comput. Interact.* **2009**, *24*, 37–41. [CrossRef]
27. Chen, C.L.; Vickerman, R. Can Transport Infrastructure Change Regions' Economic Fortunes? Some Evidence from Europe and China. *Reg. Stud.* **2017**, *51*, 144–160. [CrossRef]
28. Fang, Y.H.; Yi, J.Y. Study on Evolution Mechanism of Industrial Cluster Based on Brusselator Model. *Appl. Mech. Mater.* **2014**, *687–691*, 4832–4835.

29. Cortinovis, N.; Van Oort, F. Between Spilling over and Boiling down: Network-Mediated Spillovers, Local Knowledge Base and Productivity in European Regions. *J. Econ. Geogr.* **2019**, *19*, 1233–1260. [CrossRef]
30. Yang, X.; Zhang, H.; Lin, S.; Zhang, J.; Zeng, J. Does High-Speed Railway Promote Regional Innovation Growth or Innovation Convergence? *Technol. Soc.* **2021**, *64*, 101472. [CrossRef]
31. Lao, X.; Gu, H.; Yu, H.; Xiao, F. Exploring the Spatially-Varying Effects of Human Capital on Urban Innovation in China. *Appl. Spat. Anal. Policy* **2021**, *14*, 827–848. [CrossRef]
32. Crescenzi, R.; Rodríguez-Pose, A.; Storper, M. The Territorial Dynamics of Innovation in China and India. *J. Econ. Geogr.* **2012**, *12*, 1055–1085. [CrossRef]
33. Dakhli, M.; De Clercq, D. Human Capital, Social Capital, and Innovation: A Multi-Country Study. *Entrep. Reg. Dev.* **2004**, *16*, 107–128. [CrossRef]
34. Deng, L. The Effect of FDI Spillover and Efficiency of Independent Technological Innovation: The Perspective of Industrial Characteristics of High-Tech Industries. *Collect. Essays Financ. Econ.* **2010**. [CrossRef]
35. Marrocu, E.; Paci, R.; Usai, S. Proximity, Networking and Knowledge Production in Europe: What Lessons for Innovation Policy? *Technol. Forecast. Soc. Chang.* **2013**, *80*, 1484–1498. [CrossRef]
36. Lee, N. Migrant and Ethnic Diversity, Cities and Innovation: Firm Effects or City Effects? *J. Econ. Geogr.* **2015**, *15*, 769–796. [CrossRef]
37. Mattessich, P.W.; Monsey, B.R. *A Review of Research Literature on Factors Influencing Successful Collaboration*; Amherst H. Wilder Foundation: St. Paul, MN, USA, 1992; ISBN 0940069024.
38. Malecki, E.J. Technology and Economic Development: The Dynamics of Local, Regional, and National Competitiveness.: Edward J. Malecki. Addison Wesley Longman Ltd., Essex, 1997; xvi+460 pages: Tables, figures, bibliography, and index. *Technol. Forecast. Soc. Chang.* **1999**, *62*, 263–266. [CrossRef]
39. Audretsch, D.B.; Feldman, M.P. *Chapter 61 Knowledge Spillovers and the Geography of Innovation*; Elsevier Inc.: Amsterdam, The Netherlands, 2004; Volume 4, ISBN 9780444509673.
40. Dong, X.; Zheng, S.; Kahn, M.E. The Role of Transportation Speed in Facilitating High Skilled Teamwork across Cities. *J. Urban Econ.* **2020**, *115*, 103212. [CrossRef]
41. Acs, Z.J.; Anselin, L.; Varga, A. Patents and Innovation Counts as Measures of Regional Production of New Knowledge. *Res. Policy* **2002**, *31*, 1069–1085. [CrossRef]
42. Murata, Y.; Nakajima, R.; Okamoto, R.; Tamura, R. Localized knowledge spillovers and patent citations: A distance-based approach. *Rev. Econ. Stat.* **2014**, *96*, 967–985. [CrossRef]
43. Campante, F.R. Long-Range Growth: Economic Development in the Global Network of Air Links. *SSRN Electron. J.* **2016**, *133*, 1395–1458. [CrossRef]
44. Lin, Y.; Qin, Y.; Sulaeman, J.; Yan, J.; Zhang, J. Facilitating Investment Flows: Evidence from China's High-Speed Passenger Rail Network. *SSRN Electron. J.* **2019**, *1*. [CrossRef]
45. Kim, J.Y.; Han, J.H. Straw Effects of New Highway Construction on Local Population and Employment Growth. *Habitat Int.* **2016**, *53*, 123–132. [CrossRef]
46. Griliches, Z. Patent Statistics as Economic Indicators: A Survey. *J. Econ. Lit.* **1990**, *28*, 1661–1707.
47. Cao, J.; Liu, X.C.; Wang, Y.; Li, Q. Accessibility Impacts of China's High-Speed Rail Network. *J. Transp. Geogr.* **2013**, *28*, 12–21. [CrossRef]
48. Gao, X. Urban Sizes, Human Capital and Innovative Capacities of China Cities. *J. Soc. Sci.* **2015**, *3*, 49–58.
49. Dahlman, C. Innovation Strategies of Three of the BRICS: Brazil, India and China—What Can We Learn from Three Different Approaches? *Work. Pap. Ser.* **2015**, *1*, 100.
50. Hanley, D.; Li, J.; Wu, M. High-Speed Railways and Collaborative Innovation. *Reg. Sci. Urban Econ.* **2021**, *93*, 103717. [CrossRef]
51. Zhang, M.; Liu, X.; Ding, Y. Assessing the Influence of Urban Transportation Infrastructure Construction on Haze Pollution in China: A Case Study of Beijing-Tianjin-Hebei Region. *Environ. Impact Assess. Rev.* **2021**, *87*, 106547. [CrossRef]
52. Duflo, E.; Pande, R. Dams. *Q. J. Econ.* **2007**, *122*, 601–646. Available online: https://www.jstor.org/stable/25098854 (accessed on 11 June 2022). [CrossRef]
53. Li, X.Z.; Ji, X.L.; Zhou, L.L. Can High-Speed Railway Improve Enterprises' Resource Allocation? Micro-Evidence from the Annual Survey of Industrial Firms in China and High-Speed Railway Geographic Data. *Econ. Rev.* **2017**, *110265*, 110493.
54. Liu, C.; Lian, Z. Expressway Construction and Regional Economic Development: Evidence from China's County Level. *Econ. Sci.* **2014**, *2*, 55–67. [CrossRef]
55. Knox, S.; Bickerton, D. The Six Conventions of Corporate Branding. *Eur. J. Innov. Manag.* **2003**, *37*, 998–1016. [CrossRef]
56. Jin, M.; Gong, L.; Cao, Y.; Zhang, P.; Gong, Y.; Liu, Y. Identifying Borders of Activity Spaces and Quantifying Border Effects on Intra-Urban Travel through Spatial Interaction Network. *Comput. Environ. Urban Syst.* **2021**, *87*, 101625. [CrossRef]