Transportation infrastructure and capital mobility: evidence from China's high-speed railways

Transportation infrastructure and capital mobility: evidence from China's high-speed railways

Cite this article as: Liaoliao Duan, Dongxiao Niu, Weizeng Sun and Siqi Zheng, Transportation infrastructure and capital mobility: evidence from China's high-speed railways, The Annals of Regional Science https://doi.org/10.1007/s00168-021-01059-w

Transportation Infrastructure and Capital Mobility:

Evidence from China's High-Speed Railway

Abstract: Using the data on venture capital investment in China and high-speed railway (HSR) construction as a natural experiment, this study presents empirical evidence about the impact of transportation infrastructure on capital mobility. The study finds that one new HSR train serving a city increases venture capital inflow to and outflow from that city by 1.0% and 1.6%, respectively. The heterogeneous analyses indicate that small cities, high-tech industries, and younger firms are significantly affected by HSR connections, which show that the accelerated information transmission and investors' incremental growth expectations may account for the observed effect.

Key words: Transportation infrastructure; High-speed railway; Capital mobility; Venture capital

JEL Classification: R12, R41, G24

I. Introduction

Transportation infrastructure facilitates agglomeration and specialization of economic activities, in addition to reducing the cost of goods transportation and face-to-face meetings. The development of intercity transportation (e.g., high-speed railways) has helped geographically remote firms in connected cities improve access to information. Knowledge spillover from these firms or cities broaden their investment opportunities and significantly improve their investment returns. Several studies have examined the impact of transportation costs and proximity on the development of economic activities; however, information about the role of transportation costs in intercity capital mobility is scarce. Studies have not addressed the following issues: Does transportation infrastructure significantly increase intercity capital mobility? What types of city and firm experience larger boosts following transportation upgrade? Understanding the effect of transportation infrastructure on capital mobility is important in several ways. First, capital flow is key to economic growth as facilitates the growth of total factor productivity (Tang and Chyi, 2008), firm establishments (Samila and Sorenson, 2011), employment (Belke et al., 2003; Samila and Sorenson, 2011), innovation in OECD countries (Potterie and Romain, 2004; Aldrich and Yang, 2014; Faria and Barbosa, 2014), and GDP (Kolmakov et al., 2015; Pradhan et al., 2016). Therefore, economists and policymakers face the challenge of understanding the factors that stimulate capital mobility. Second, investment in transportation infrastructure is a costly and prominent policy tool for a country that directly affects the degree and distribution of within-country capital flow. Therefore, a comprehensive estimation of the effect of investment on capital mobility is fundamental to understanding both investment efficiency and incremental effect on regional economic growth and the distribution of economic activities.

Two problems hinder these issues: first, the lack of detailed information on locations of investment source and destination of intercity capital flow and second, the impact of missing variables on the construction of transportation infrastructure and capital mobility, which may contradict the establishment of causality between transportation and capital flows.

This study addresses both issues. It uses intercity venture capital (VC) investment as a proxy for capital mobility and implements an instrumental variable approach to mitigate the endogeneity of transportation infrastructure construction. This study is based on data describing VC investment drawn from the Zero2IPO Database from 2007 to 2015, which identifies locations of both investors and investee firms for each investment event. The total inflow and outflow VC investment are then aggregated at the city level. In terms of transportation infrastructure, this study uses the high-speed railway (HSR) project in China as a natural experiment to examine the effects of reduction in passengers' travel cost on capital mobility. To accelerate information exchange and cooperation across different regions, the Chinese government revised its *Mid-to-Long-Term Railway Development Plan* in 2008 to construct the *Four Vertical and Four Horizontal HSR framework*.[1] As VC only represents a

[1] The four vertical HSR lines consist of Beijing–Shanghai, Beijing–Wuhan–Guangzhou–Shenzhen (Hong Kong),

small portion of the total investment,[2] the spatial placement of HSR lines and stations may not be substantially affected by VC investments. Hence, reverse causality is not a concern in this study. To resolve the potential endogeneity problem that HSR construction is common in cities with more capital flow, an instrumental variable is constructed for a city's likelihood to be connected in the HSR network using the variation in historical railway network (Zheng and Kahn 2013; Duranton et al., 2014; Niu et al., 2020).

A two-way fixed-effects model shows that connection with an HSR network significantly increases VC investment in and out of the connected city. The two-stage least squares (2SLS) estimates suggest that one new HSR train connecting the city increases the VC inflows and outflows by 1.0% and 1.6%, respectively. To validate the results, the potential bias is eliminated from the measurement errors using alternative measurements of VC and HSR connections. Second, the research sample is limited to cities connected to the HSR network by late 2015. The robustness for subsamples that exclude China's 35 major cities is tested. To explore the working mechanisms, the heterogeneous effects are examined with regard to city size, industry, and firm size and the information accessibility and growth expectations channels representing the observed effects are proven.

This study contributes to the literature as follows. First, several studies have empirically estimated the effects of transportation infrastructure on local economic growth and focused on its impact on GDP growth (Berger and Enflo, 2017; Lin et al., 2019; Banerjee et al., 2020), employment and specialization (Lin et al., 2017; Dong, 2018), trade (Duranton et al., 2014; Martincus et al., 2017; Donaldson, 2018), educational investment (Adukia et al., 2020), urban growth (Duranton and Turner, 2012; Faber, 2014), urban form (Baum-Snow, 2007; Baum-Snow et al., 2017), and intercity industrial reshuffle (Li and Xu, 2018). This study contributes to the literature by estimating the effects of intercity passenger transportation on capital mobility. New evidence is provided on the underlying channels by which transportation infrastructure facilitates regional economic growth.

Second, it also contributes to the literature on the economic effects of HSR projects in the world. Most studies that focus on HSR projects in Japan, Europe, and China have assessed their effects on local economic development (Sasaki et al., 1997; Ahlfeldt and Feddersen, 2010; Mart-Henneberg, 2000; Coto-Millán et al., 2007; Andersson et al., 2012; Zheng and Kahn, 2013; Bernard et al., 2015; Ke et al., 2017). Lin (2017) investigated how intercity passenger transport shapes urban employment and specialization patterns. Lin et al. (2018) revealed the role of HSR in metropolitan passenger mobility. Qin (2017) and Lin et al. (2019) showed the negative impact of HSR on GDP per capita of peripheral counties, which is primarily driven by capital input contraction, industrial output reduction, and skilled labor

---

Beijing–Shenyang–Harbin (Dalian), and Shanghai–Hangzhou–Ningbo–Fuzhou–Shenzhen. The four horizontal HSR lines include Xuzhou–Zhengzhou–Lanzhou, Shanghai–Hangzhou–Nanchang–Changsha–Kunming, Qingdao–Shijiazhuang–Taiyuan, and Shanghai–Nanjing–Wuhan–Chongqing–Chengdu.

[2] In 2015, the national VC investment amount (including both intercity and intracity deals) was 259 billion RMB, accounting for only 0.4% of national total fixed asset investments (55,159 billion RMB).

outflow. This study investigates the HSR effect from the perspective of venture capital investment, which is crucial for regional entrepreneurship and innovations.

Finally, this study supplements studies on the determinants of VC investment. Studies have shown a negative relationship between geographic distance and VC investment likelihood, while the experiences of VC and syndication networks further extend the spatial reach of VC investments (Sorenson and Stuart, 2001; Cumming and Dai, 2010). Giroud (2013) and Bernstein et al. (2016) documented that airline routes increase the likelihood and performance of intercity investment. Similar to the present study, Long et al. (2016) and Duan et al. (2020) examined the impact of HSR on VC inflows. However, this study differs from their research from several perspectives. The present study uses the variation in HSR connection intensity, while most studies focus on the impact of the increase in travel speed. Although the travel speed is important, it changes immediately after a city is connected to HSR, regardless of the number of stations or trains serving the city. To state that a city with a small HSR station serving a few trains each day benefits from the entire HSR network as much as a city with a large station serving hundreds of trains each day would be arbitrary. The connection frequency measure in the study helps quantitatively examine the extent to which transportation connection affects capital mobility. This study and that by Duan et al. (2020) also differ as they focused on the impact of HSR and airline network in shifting VC investment at the city pair level; however, whether HSR access has any aggregate impact at the city level remains debatable. Our city-level estimation helps thoroughly understand the net effect of HSR connection on the regional economic outcome, especially when displacement may occur that a positive effect from the capital communication with one city is accomplished at the cost of a decline in capital mobility with another city. This study also proposes an increase in the growth expectation by investors to explain how transportation upgrade affects capital mobility. The growth expectation mechanism does not require investors and investees to be directly connected. Instead, it shows an indirect effect of the HSR expansion.

This paper is presented as follows. Section II provides the institutional background of HSR and VC investment in China, and the conceptual framework of this study. Section III describes the data and outlines the empirical approach and the endogeneity issue. Section IV presents the main results, robustness checks, and heterogeneity analyses and Section V concludes.

II. Background and Theoretical Framework

2.1 HSR network in China

In 2008, the State Council revised *Mid-to-Long-Term Railway Development Plan* (2008) and initiated the *Four Vertical and Four Horizontal HSR network*, which consists of four north–south and four east–west rail corridors. This HSR framework establishes connections between metropolitan cities, provincial capitals and major sub-provincial cities and expands the network to other widely spaced, population-dense cities with diverse natural resources in western China. According to the *Ministry of Transport*, both placement of stations and opening of lines would be devised based on comprehensive socioeconomic factors, including economic development, population and resource distribution, national security, environmental concerns, and social stability of each region. Figures 1a and 1b illustrate the dynamics of HSR operation mileage and passenger traffic volume from 2008 to 2015, respectively. From 2008 to 2015, the operation mileage of HSR increased rapidly from 672 kilometers to 19,838 kilometers. Moreover, HSR has become a popular transportation mode, accounting for 37.9% of total railway passenger traffic volume as of 2015.

// Insert Figure 1 about here //

According to differences in the designed highest speed and coverage areas, China's high-speed trains are further categorized as G-, C-, D-series. The "names" G, C, and D correspond to the initials of Chinese words "***G**aotie*, ***C**hengji*, and ***D**ongche*." G-series HSR is designed primarily to speed above 300 km/h and is the core of China's nationwide HSR system. C-series HSR, whose highest speed is not less than 250 km/h, mainly connects adjacent cities or those within a metropolitan area. D-series HSR also runs nationwide but often has a limited highest speed of 250 km/h. As of 2015, these three types of HSR in China accounted for 40.57%, 18.15%, and 41.27%, respectively. The following empirical analyses treat all three types of HSR trains without distinction. However, this study examines the possible impact of the speed differences in the three types of HSR on the empirical results for robustness by introducing a speed-weighted HSR connection measurement.

2.2 Venture capital investment in China

The Chinese government recognized the value of VC in its policy considerations and founded its first VC institution in 1985. Therefore, VC has dual roles in China: a high-risk and high-yield professional equity investment. It is an important technique to improve scientific innovation capacity, cultivate emerging industries, and promote economic development. However, the growth of VC investment during the 1980s was tardy. In 1988, VC investment accounted for only 3.7% of the total funds for technology. In the mid-1990s, the government's perception of VC changed from a government financing activity to a market-oriented one that supports industrialization of new technologies. In 1999, the State Council issued *Opinions on Establishing a Risk Investment Mechanism*, which promoted VC institutions. In the early 2000s, China's VC industry developed rapidly, but domestic VC still faced several difficulties compared with foreign VC. Foreign VC addressed the barriers of policy restrictions on investment, and, concurrently, the firms they chose to invest enjoyed benefits as Sino-foreign joint ventures. Therefore, foreign VCs in China performed much better than domestic VCs and dominated most of China's VC activities. Since the revised *Company Law* and *Security Law* was implemented in 2006, the Chinese government greatly reduced the legal barriers to domestic VC in terms of organizational form, fundraising form, registration qualification, etc. Since then, China's VC industry continues to grow substantially. The Shanghai-Hongkong Development Institute reported that in June 2018, the number of VC institutions in China was 27,466 and the total amount of management capital reached 11.2 trillion RMB yuan (about 1,670 billion USD).

2.3 The relationship between HSR network and venture capital flow

Wright Robbie (1998) and Portes and Rey (2005) claimed that VC investments are constrained by information asymmetries, because collecting information of newly established start-ups in remote cities is often difficult. Similarly, Sorenson and Stuart (2001) showed a negative relationship between geographical distance and VC investment likelihood. Cumming and Dai (2010) revealed that information asymmetries eventually lead to negative performance in VC investment deals; thus, VCs prefer local startups. HSR expansion, however, largely reduces the transportation cost of intercity travel and facilitates face-to-face communications, thus directly reducing the cost of information exchange and increasing opportunities for cooperation between VC investors and investees in different cities. Therefore, conceptually, expansion of HSR network accelerates VC mobility as it effectively facilitates the exchange of intercity information.

Besides information acceleration resulting from direct HSR connections between the VC investor and investee, HSR also affects the VC investment activity through a growth expectation channel. Thus, HSR expansion substantially promotes cities' economic potential (Lin 2017; Zheng and Kahn, 2013), which is an indicator of the investee companies' growth potential under incomplete information and helps investors reinforce the company's future market performance. When VC investors decide on investment, they consider various factors to assess the investment values, including a city's socioeconomic fundamentals and growth potential. Successful startups often arise from cities with high development potential. Chen et al. (2010) found that superstar cities with promising fundamentals and growth expectations attract more than 50% of VC investment deals in the United States. Similarly, Gibbons and Wu (2017) suggested that transportation infrastructure gives better access to domestic markets and the growth expectation of cities. Cities with high development potential provide a better business environment, policy support, and market demand, which contribute to the growth of investee firms. Therefore, HSR connections attract more VC inflow by presenting a positive market potential to investors.

III. Data and Empirical Approach

3.1 Data Description

This study uses the VC investment data (2007–2015) from Zero2IPO Database (www.pedata.cn) to measure the capital mobility across cities. The Database reports detailed information of each investment activity, including amount of investment, names and location of both investors and investees, industry type, and development stage of investees. Based on the location information, all investor and investees are located at the prefecture-city level. For any VC investment events reported in US dollars, the investment amounts are converted to RMB yuan based on the exchange rate[3] at that time. Given the information on industry type, the two-digit industry code for each investee can be identified according to the National Economic Industry Classification standard (GB/T 4754-2017). In total, 22,677 intercity VC investment events across 130 cities appeared in the dataset. Subsequently, the total inflow and outflow of VC investment were aggregated for each city each year to construct a city-level panel dataset. Venture capital inflow to a city is defined as the total VC investment received by investee companies in that city from those in other cities. Similarly, venture capital outflow from a city means the VC investment by investors located in that city to investee companies in other cities. Figure 2 illustrates the spatial characteristics of VC flows in 2007 and 2015, respectively. The number of intercity VC flows increased from 207 in 2007 to 1,158 in 2015. Thus, VC mobility soared during our research period. Figure 2 shows that Beijing, Yangtze River Delta, and Pearl River Delta are the centers of VC investment activities.

// Insert Figure 2 about here //

To observe the dynamics of national HSR network expansion, we manually collected detailed information on each HSR train from the *Train Schedule Books* from 2007 to 2015, officially published by *China Railway Publishing House*. The books provide detailed information about the stations and schedules for each HSR train. Specifically, there were 417 HSR trains with 70 HSR stations in 2007, 1,223 HSR trains with 234 HSR stations in 2011, and 3,140 HSR trains with 610 HSR stations in 2015. Based on the names of the HSR stations, information on their longitude and latitude was collected, and geocode assigned on an electronic map. Notably, after matching station locations on city maps, could compute the number of HSR trains serving each city[4] each year. With this continuous variable of HSR

[3] Historical exchange rates are collected from CSMAR Database (www.gtarsc.com).

[4] As there may be more than one HSR station for the connected cities and we have no access to the exact longitude and latitude for each VC participant, all the stations within a city are treated as a whole and transportation within the city were not considered. Specifically, information on both VC and HSR was aggregated at the city level. For

connections, a panel of HSR data was constructed with a detailed description of the connection status and connection frequency.

Figure 3 presents the daily number of HSR trains in operation and the annual VC investment between 2007 and 2015 and shows a significant positive correlation between HSR construction and VC investment. From 2007 to 2015, the total number of intercity VC investments increased from 1,501 million RMB yuan to 35,071 million RMB yuan. The annual growth rate in VC investment is nearly 48%. Figure 4 plots the VC flows and HSR connections[5] of each city in 2015 and shows that the number of HSR connections is positively correlated with the scale of VC flows. The single regressions indicate a 1.8% increase in VC flows for each additional HSR connection.

// Insert Figures 3 & 4 about here //

Socioeconomic data for each city, such as prefecture-level GDP, the GDP share of the three industries, employment, the loan balance of financial institution, and deposit balance of financial institution, are collected from China City Statistical Yearbooks from 2007 to 2015.

3.2 Empirical Approach

The study aims to obtain the causal effects of HSR connection on VC investment flows. Thus, it relies on the fixed-effects model and the difference-in-difference (DID) model on city-level panel data. The model specification is as follows:

$$\ln y_{it} = \alpha + \beta \cdot hsr_{it} + \gamma \cdot X_{it} + \rho_i + \tau_t + \varepsilon_{it} \qquad (1)$$

where y_{it} is the total value of VC inflow or outflow of city i in year t; its logarithmic form is used as the dependent variable. hsr_{it} is the main explanatory variable that measures the frequency of HSR trains serving city i in year t. In the DID model, we replace the explanatory variable with a dummy variable hsr_post_{it} indicating whether city i has HSR operation in year t. X_{it} is the vector of economic variables to control for time-variant factors that affects a city's VC flows, including prefecture-level GDP, employment, loan balance of financial institutions, deposit balance of financial institutions, and GDP share of tertiary industry. ρ_i is the city fixed effects, which captures all city-level time-invariant characteristics such as

instance, if there are 50 HSR trains in *Shanghainan* station and 30 in *Shanghaixi* station, then based on our definition, there are 80 HSR connections for Shanghai. For future study, researchers could introduce a more precise transportation measure by geocoding every HSR location and calculate the accessibility of the stations to better examine the effect of transportation on other outcomes.

[5] The frequency of HSR connections to a city is the city-level HSR trains that depart, stop by, or arrive at the city. For instance, we assume that there are only two trains under operation – G10 and G30. The stops of G10 are Shanghai–Nanjing–Jinan–Beijing, and the stops of G13 are Beijing–Jinan–Nanjing–Suzhou–Shanghai. Thus, while the total number of HSR trains here are 2, the HSR connections for Beijing, Jinan, Nanjing, Suzhou, Shanghai are 2, 2, 2, 1, and 2, respectively.

geographical features and city hierarchy. τ_t denotes the year fixed effects capturing all time-variant factors common to all cities such as the macroeconomic conditions and interest rate. ε_{it} is the error term. To handle potential heteroskedasticity and serial correlation, standard errors are clustered at the city level. Table 1 summarizes the descriptive statistics for the variables in Equation (1).

// Insert Table 1 about here //

3.3 Identification Strategy

To address the omitted variable problem in fixed effects model, this study follows the study by Niu et al. (2020) and constructs a panel-structured instrument using historical railway connection. Their approach assumes that the total number of newly constructed HSR lines and stations at the country-level HSR plan is exogenously determined by the central government. This assumption holds for two reasons: (1) the HSR network is a national-level construction project, which considers the national factors (e.g., central government budget), rather than the local demand or local economic status, as the first-order factors; and (2) the central government exclusively plans the land-use quota, including the land allocated for HSR station and line construction, which determines the total number of new HSR stations that can be built each year.

Specifically, the approach in the study comprises two steps. First, information on Chinese railway network in 1978 was collected. Totally, 119 cities operated railway in 1978 with different connection intensity (i.e., the number of trains departed, stopped by, and arrived at the city). These 119 cities were ranked by their connection intensity from large to small. Second, for each year of the study period (2007–2015), if there were N cities operating HSR, the top N cities were selected in the 1978 railway connection intensity list as the hypothesized HSR-connected cities in that year. Mathematically, the total number of HSR cities per year is

$$N_t \ (t = 2007, 2008, \dots, 2015),$$

and city i's rank in the 1978 railway connection list (from large to small) is

$$M_i \ (i=1, 2, \dots, 119),$$

Thus, the instrumental variable for city i in year t

$$hsr\_iv_{it} = \begin{cases} 1, & \text{if } M_i \le N_t \\ 0, & \text{if } M_i > N_t \end{cases}$$

The underlying rationale for our instrument construction approach is that the spatial placement of both HSR lines and stations is jointly determined by the central and local governments through a serious bargaining process (Li et al., 2018). If the central government determines the total scale of new HSR constructions each year, the local government of a city with historical railroads gains more bargaining power, and the city is more likely to receive an

HSR assignment. As several factors are considered in HSR station placement, the construction cost is the most critical. Stations or lines renovated or built on historical railway stations or lines can save huge construction costs in land acquisition, route designing, and leveling and grading the roadbed. Therefore, a historical railway network is a good predictor of the modern railway network.

It is a concern that cities with railway stations in 1978 could progress and become more populous, which violates the orthogonal assumption between a valid instrument and the equation error term ("exclusion restriction" of IV approach). To address the issue that larger cities may receive railroads, and large cities in 1978 tend to be large today and have more VC flows, we control for the contemporaneous employment scale in all regressions. Table A1 reports the results of both the relevance and exclusion restriction tests.[6]

As for the DID model, we examine the parallel trend hypothesis to relieve the endogeneity concerns. To do that, we estimate the coefficients for a series of dummy variables relative to the opening year of HSR as follows:

$$\ln y_{it} = \alpha + \sum_{n=-4}^{4} \beta_n \cdot hsr_{it}^{n} + \gamma \cdot X_{it} + \rho_i + \tau_t + \varepsilon_{it} \quad (2)$$

where hsr_{it}^{n} represents the n^{th} year relative to the opening year of HSR. A positive value of n indicates the n^{th} year after the first year of HSR operation and a negative n value indicates the n^{th} year before the opening of HSR; n = 0 indicates the HSR opening year. To focus on the variation around the opening time of HSR, we set the range of n to be [-4,4]. Specifically, n = 4 indicates the 4th year after the opening year of HSR and later periods, and n = -4 indicates the 4th year before the opening of HSR and earlier periods. We use n = -1 as the base year and have it dropped from the regression.

IV. Empirical Results

4.1 Main Results

The estimation results, presented in Table 2, are the central estimates of this study. Each column reports the result of one regression from Equation (1). Columns (1) and (2) present the OLS estimation of the effect of HSR connections on VC inflow and outflow, respectively. Columns (3) and (4) report the corresponding 2SLS regression using the historical railway network as an instrument. In addition, we demonstrate the DID estimations for main results in Columns (5)-(6) of Table 2.

Table 2 reveals two central findings. First, the significantly positive estimates for HSR connections in all regressions indicate that it substantially increases VC mobility in both

[6] Column (1) of Table A1 reports the first-stage specification result, suggesting that our IV is significantly correlated with the key explanatory variable, *hsr*. The F-statistics is 13.58, indicating a pass of the weak IV test. Columns (2) to (7) of Table A1 show the empirical test for exclusion restriction where we include both the HSR and 1978 railway connection in the second-stage regression. In all regressions, the coefficients of IV are insignificant, indicating that the IV only affects the VC flow through the channel of HSR construction.

capital inflows and outflows. The results in columns (1) and (2) suggest that an additional HSR connection to a city increases VC inflow and outflow by 0.4% and 0.6%, respectively. After implementing the instrumental variable approach, the effects of HSR connection on VC inflow and outflow increase to 1.0% and 1.6%. The coefficients of DID model indicate that the connection of HSR leads to 35.1% and 23.3% increase in VC inflows and outflows. The underestimation of the effects in OLS is probably introduced by omitted variables having different effects on the HSR connection and VC investment. For example, geographical complexities (e.g., mountains and harsh conditions) of some inland areas do not favor the construction of HSR lines but lower rents and tax abatements in these areas help develop emerging firms. Given that the average number of daily HSR connections in 2015 was 71.4, the average increased VC inflow from HSR connections is 71.4% or 20.7 million RMB yuan.[7] According to Belke et al. (2003), the increase in VC investment would further bring 0.4% to 2.2% employment growth for cities.[8]

With regard to the other city attributes, employment scale shows a significantly positive correlation with VC flows, consistent with findings from Belke et al. (2003). After controlling for employment scale, GDP and the share of tertiary industry show no significant effect on VC mobility. The correlation between VC flows and deposit balance of financial institutions is positive and nearly significant, while loans from local banks are positively correlated with VC inflows but negatively insignificantly correlated with VC outflows. This is consistent with the positive correlation between VC investment and financial market development found by Pradhan et al. (2018).

// Insert Table 2 about here //

Finding a spurious correlation between VC flows and HSR connections is a problem if the trends in VC flows are not parallel between the two groups (HSR-connected cities and non-connected cities) before the HSR operation. To check whether the parallel trend assumption holds, we report the event study analysis results in Appendix Table A2 and Figure A1. Specifically, columns (1)–(6) of Appendix Table A2 present the results on both VC inflow and outflow in terms of total investment value, involved firms, and investment events. We use $n = -1$ as the base year and exclude it from the regression. The coefficients for the lead treatment variables (*before4-before2*) are not significantly different from zero, indicating that there is no observable difference between the HSR-connected and non-connected cities before HSR operation. Appendix Figure A1 demonstrates the 95% confidence interval for the treatment effect each year, which further supports our conclusion.

4.2 Robustness Checks

This subsection focuses on the robustness checks on the study results.

[7] The coefficient of HSR for capital inflow (0.010) multiplied by the average HSR connections (71.4) is equal to 71.4%. The average venture capital inflow is 29.1 million, so 71.4% of this is 20.7 million.

[8] Belke et al. (2003) report the elasticity of VC investment with respect to employment ranging from 0.006 to 0.03, so the employment growth rate caused by VC is between 0.3% and 1.8%.

Alternative venture capital measurement

The main specification uses the total value of a city's VC investment as the measure of capital flows. This subsection constructs two other VC measurements, that is, the total number of investee firms and investment events, to check the robustness of the main finding. Table 3 reports the regression results. Column (1) shows the capital inflow of city *i* measured by the total number of firms in city *i* that receive VC investment from other cities. Column (2) shows the capital outflow of city *i* measured by the total number of firms in other cities that receive VC investment from city *i*. Similarly, column (3) shows the capital inflow of city *i* measured by the total number of VC investment events in city *i* from other cities' VC investors. Column (4) shows the capital outflow of city *i* measured by the total number of VC investment events in other cities from city *i*'s VC investors. The coefficients of *hsr* are significantly positive, showing the robust effect of HSR connections on VC flows in both investment value and frequency. If there is one more HSR train connecting the city, the number of investee companies and investment events from other cities increases by 0.6% and 0.7%, respectively, and the number of firms and events invested by HSR-connected cities also increases by 0.5% and 0.7%, respectively. Unlike the main results, similar effects are found from HSR connection on the amount of VC inflow and outflow. Combined with the different effects on the value of VC inflow and outflow, this implies that HSR connections hugely increase the amount of each outflow investment.

// Insert Table 3 about here //

Alternative HSR measurement and speed weight

The baseline model uses the number of HSR connections as the main explanatory variable. However, a decline is possible in the marginal effect of an additional HSR train serving one city. To leverage the HSR network data, the number of cities (rather than the number of HSR trains) connected to each city through HSR is calculated, which is then used as an alternative measurement of the HSR connection. Columns (1) and (2) of Table 4 report the new results. Similar effects are found in the HSR connections on VC flows: one more city connected through HSR leads to a 2.5% increase in VC inflow and a 3.8% increase in VC outflow.

Heterogeneity in the travel speed of different series of HSR is another challenge of the measurement of HSR connection. The highest speeds of G-, C-, and D-series HSR are generally designed to be over 300 km/h, 250 km/h, and 200 km/h, respectively. A higher speed significantly increases the efficiency of communication. To reflect the possible impact of travel speed, we set a speed weight of G-, C-, and D-series HSR as 1, 0.83, and 0.67, respectively, which are calculated by the ratio of their designed highest speed to G-series highest speed. The HSR connection in Equation (2) is recomputed by considering the speed weights. Specifically, if city *i* is connected by one G-series HSR, one C-series HSR, and one D-series HSR connection, the weighted *hsr* equals $1 \times 1 + 1 \times 0.83 + 1 \times 0.67 = 2.5$. Columns (3) and (4) of Table 4 show the regression results. After considering speed weight, the effects of HSR connection on VC flows are nearly unchanged, with 1.0% and 1.7% increase in capital inflows and outflows for each additional HSR connection.

// Insert Table 4 about here //

Sample selection

Although an instrumental variable is used to handle the potential omitted variable problem, this empirical method still suffers from the incomparability issue between the treatment and control group. Persson and Tabellini (2007) stated that a comparison between different observations with different treated dates within the treatment group help identify the causal effect if they are assumed to enjoy high similarity in both observables and unobservables. In the study sample, 98 cities had already had HSR access at some point during the study period. The 2SLS estimation of Equation (1) is repeated by restricting the samples only to these 98 cities. Columns (1) and (2) in Table 5 present the results. The coefficients estimated are still significantly positive but larger, suggesting that a new HSR train connecting the city increases the VC inflows and outflows in the city by 1.6% and 2.1%, respectively.

Another concern is that the main finding may be driven by megacities and regions' central cities, such as Beijing, Shanghai, Shenzhen, and Guangzhou. The study shows that 35 major cities[9] in China operated 227 HSR trains on average during the study period, a number much higher than the other 245 cities with 50 operated HSR trains on average. Meanwhile, VCs consider these major cities more favorably as they offer high-quality economic fundamentals. Columns (3) and (4) re-estimate Equation (1) by excluding the 35 major cities from the study sample and find that the effect magnitude of HSR connection on VC flows is similar to that seen in the main results.

// Insert Table 5 about here //

4.3 Heterogeneous Effects

The results thus far estimated the average effect of HSR connections on VC inflow and outflow. With the information on the characteristics of city, industry, and investment event, further in-depth study is conducted by examining the heterogeneous effects.

City size

[9] The 35 major cities in China include Beijing, Tianjin, Shijiazhuang, Taiyuan, Hohhot, Shenyang, Dalian, Changchun, Harbin, Shanghai, Nanjing, Hangzhou, Ningbo, Hefei, Fuzhou, Xiamen, Nanchang, Ji'nan, Qingdao, Zhengzhou, Wuhan, Changsha, Guangzhou, Shenzhen, Nanning, Haikou, Chongqing, Chengdu, Guiyang, Kunming, Xi'an, Lanzhou, Xining, Yinchuan, and Urumchi.

The study first examines whether the effects of HSR connections on capital mobility differ from city size. All 280 cities are divided into two groups based on their GDP in 2006 before the study period. If the city's GDP level was above the median value, it is categorized as a big city, otherwise small. Table 6 presents the subsample regression results and reveals two main findings. First, the number of HSR connections in big cities significantly increases their VC inflows with each new HSR connection by 0.5%. However, no significant effects of HSR connections were found on VC inflow to small cities. Second, both groups of cities experience an increase in VC outflow because of more HSR connections, and the effect is much larger for small cities than for big cities. Overall, these results imply that HSR connections increase VC flows from small cities to big cities. These results are consistent with our expectation that big cities, which already enjoy convenient transportation such as airplanes and expressways, experience smaller improvements in communication with other cities after operating HSR. However, by increasing the accessibility of small cities, HSR connections dramatically alter their growth patterns, particularly in growing areas initially constrained by transportation. VC investors from small cities now have better access to the national market and proactively seek more investment opportunities.

// Insert Table 6 about here //

Industry sector

Venture capital is key to promoting high-tech industries and industrial structure upgrades. The study examines the heterogeneous effects of HSR connections on VC flows in different industries. First, the VC inflows and outflows are separately calculated for the primary (cultivation and acquiring raw materials), secondary (manufacturing and construction), and tertiary (service) industry sectors for each city. The regression results are presented in Table 7a. All coefficients are positive and statistically significant or marginally significant, indicating that HSR connection promotes capital mobility in all three sectors. Specifically, a new HSR connection increases VC inflows of the primary, secondary, and tertiary sectors by 0.4%, 0.5%, and 1.3%, respectively and the positive effects on VC outflows of the city's primary, secondary, and tertiary industries are 0.4%, 1.0%, and 1.8% respectively. Particularly, the coefficients for the tertiary sector are more than two times that for the other two sectors, indicating that the number of HSR connections has a greater effect on capital mobility in the tertiary sector.

// Insert Table 7a about here //

Second, the firms are classified as high-tech and non-high-tech industry using their 2-digit industry code based on *Standards of High-tech Enterprises Recognition* (2016) to examine whether changes to a city's HSR would affect the comparative advantage in high-tech industries. Table 7b presents the estimated results. Similar to the results in Table 7a, HSR connections have positive effects on capital mobility for both industry categories. The results confirm that investors specialize in investments in high-tech industries when they have more HSR connections. The effects on VC inflows and outflows of high-tech industries are

1.7% and 1.8%, respectively, for an additional HSR train connection, which are much larger than effects on non-high-tech industries. These results show that HSR plays an important role in reducing the cost of information transmission as the high-tech industry relies on knowledge sharing and information exchange. Second, HSR facilitates economic growth by enhancing innovation and industrial upgrades given the importance of the tertiary sector and high-tech industries.

// Insert Table 7b about here //

Investment size

HSR connections increase the average outflow value of each investment event; hence, does this also mean that there are more large-scale investments due to HSR connections? All VC investment events are divided into two groups based on their median value in the study sample. The small- and large-scale VC investments are then regressed using the baseline model. As reported in Table 8, HSR connections significantly increase VC inflow and outflow for small-scale investments by 1.3% and 1.7%, respectively, compared with 0.7% and 0.7%, respectively, for large-scale investments. The findings that HSR connections favor small-scale investments are valid because VC investors making large-scale investments are less constrained by transportation costs, and they often have access to more complete market information. However, for those making small-scale investments, transportation cost and information access restrain them from finding new investment opportunities. Therefore, with additional HSR connections, the decrease in transportation cost represents a larger fraction of their total cost of capital mobility.

// Insert Table 8 about here //

Development stage of investees

Finally, the heterogeneous effects of HSR connection on firms at different stages of development are examined. The Zero2IPO Database classifies development stages into *Seed*, *Initial*, *Expansion*, and *Mature*. The *Seed Stage* and *Initial Stage* are combined as the early stage (the firms at these two stages are categorized into young firms) and the *Expansion Stage* and *Mature Stage* as mature firms. Table 9 reports the coefficient estimates based on the development stages. The incremental effect of HSR on VC flows is larger for young firms than for mature firms. Specifically, one more HSR connection is associated with a 1.3% increase in VC inflow into young firms. However, the magnitude of the effect for mature firms is less than half of young firms. For VC outflow, columns (3) and (4) of Table 9 indicate that VC investors increase their investment in both young and mature firms in other cities if the investors' city are connected to the HSR network.

Overall, Tables 8 and 9 imply another mechanism of HSR effect on VC investment. As VC investors find it challenging to collect and assess the information on small and young firms compared with that of large and mature firms, they often rely more on city-level signals that reflect the quality of the investee company. This study shows that HSR connections are more significant for small-scale investment and young investees, indicating that VC investors are encouraged by the incremental local economic potential associated with HSR.

// Insert Table 9 about here //

Extensive margins versus intensive margins

There are two possible channels behind the HSR incremental effect on VC. First, the VC activities from/to cities that have already had VC activities before HSR might increase because HSR encourages VC investors and investees to work together more (the intensive margin). Second, VC activities might now take place from/to a new city because HSR allows faster information communication and expand the VC market across cities (the extensive margin).

To distinguish the impacts of HSR at the extensive from intensive margins, we follow Dong et al. (2020) and divide the sample cities into two groups, "first-time VC cities" and "incumbent VC cities", based on whether the city has experienced intercity VC inflow or outflow before 2007, the first year of our research period. Table 10 reports the result of heterogeneous analysis. Columns (1) and (2) present the impact of HSR on cities with and without VC inflow before 2007, respectively. We find stronger evidence for the intensive margin effect of HSR on VC inflows. This result is consistent with the heterogeneity findings on city size and reveals the potential role of HSR in widening regional capital inequality. Columns (3) and (4) report the estimations on cities with and without VC outflow before 2007, respectively. Interestingly, for VC outflow, the extensive margin is larger than the intensive margin. We find that HSR substantially broadens the geographical range of venture capitals and enables VC outflows to new cities, as those without pre-2007 VC experience benefit more from HSR connection.

// Insert Table 10 about here //

Displacement effects versus net growth effects

One potential issue for interpreting our finding of the average positive HSR effect on VC is the displacement effect. In this case, the non-HSR cities become less attractive for VC investors, and VC activities decline in response to the relative disadvantage in the VC market, which results in a displacement (relocation) of VC activities from non-HSR cities to HSR-connected cities. In this case, the increase in VC activities in HSR-connected cities comes at the cost of VC reduction in non-HSR cities. In another case, HSR would increase the aggregate (national or regional) VC activities, and no cities would lose even if there is no HSR line. To further investigate this issue, we use Propensity Score Matching (PSM) to separately look at the patterns of VC activities in different cities before and after HSR connection. If the observed HSR effect is caused by VC relocating to the HSR cities, the VC activities should decrease in non-HSR cities. In this context, the propensity score is defined as a conditional probability of assignment of HSR station in our sample period. The treated group is cities that have operated HSR between 2007 to 2015, whereas the control group is those that have never been connected to HSR.

First, we estimate a binary logit model for developing the propensity score of the HSR connection. We use the same city characteristics as that in Equation (1) as independent variables – the prefecture-level GDP, employment, loan balance of financial institutions, deposit balance of financial institutions, and GDP share of tertiary industry in 2006 (the year before our research period) – to be potential sources of HSR station selection. Second, each city that has been connected with HSR from 2007 to 2015 is matched with one non-HSR city based on the propensity score. We, therefore, split the sample into two groups of cities with similar attributes before the sample period that differs only in the HSR connection status after 2007. We can see from Appendix Table A3 that the matched city is not systematically different from the HSR-connected city, meaning that the city attributes are balanced between the matched groups.

Then, we estimate the following regression model

$$\ln y_{it} = \alpha + \sum_{n=-4}^{4} \beta_n \times hsr_{it}^n + \sum_{n=-4}^{4} \beta_n^{'} \times hsr_{it}^n \times treated_i + \gamma \times X_{it} + \rho_i + \tau_t + \varepsilon_{it} \quad (3)$$

where hsr_{it}^n represents the nth year relative to the opening year of HSR. Importantly, hsr_{it}^n of cities in the control group is assigned to the same value as their matched city in the treated group. $treated_i$ indicates whether city i is in the treated group.

Figure 5 presents the event-study results for both HSR cities (the right column) and their matched city (the left column), and Table 11 reports the coefficients of the event study. For the control group, we assume that they are connected to a hypothetical HSR in the same year as their matched HSR city. Obviously, for both groups, VC activities increase after their HSR operation, showing little evidence of the displacement effect between HSR cities and non-HSR cities. While VC activities of all cities increase, HSR-connected cities experience faster growth, as a result of which we can see the net effect of HSR on VC is positive at the city level.

// Insert Table 11 about here //

// Insert Figure 5 about here //

V. Conclusion

This study investigates the causal effect of HSR infrastructure on the level and frequency of capital mobility. The analysis reveals two main findings. First, the study finds that being connected to the HSR network significantly increases a city's VC mobility. The 2SLS estimates indicate that an additional HSR train connecting the city increases VC inflows and outflows by 1.0% and 1.6%, respectively. The findings conform to various robustness checks, including alternative VC measurement, HSR measurement, and sample selections. Second, heterogeneous analyses show that small cities, the tertiary sector, high-tech industries, and younger firms are impacted more by HSR connections, implying the important role of HSR connections in reducing the cost of information transmission and increasing investors' growth expectation, thus enhancing capital flows and innovation. Overall, the results show how transportation infrastructure affects capital flows and distribution of investment activity. A better intercity transportation network encourages VC investment and enables capital flow to small and young firms that are constrained by the communication with the capital market.

This study has several implications. First, the findings show that HSR significantly increases a city's capital mobility in terms of both VC inflow and outflow. Cities with advanced transportation network attract more inter-regional capital mobility. These estimates help inform city planners and policymakers in framing infrastructure policy. Second, there is substantial heterogeneity in the treatment effect of HSR. Particularly, the effect is stronger for young and small firms that are initially at a disadvantage of attracting VC investors. However, small cities, although experiencing a prominent increase in VC outflow, are not favored in HSR-induced VC inflow, suggesting a possible disparity in terms of the spatial distribution of the incremental investments across the landscape. Third, as economic growth and capital flows are in tandem, the transportation upgrades pursued by cities pursue help achieve greater development of local economies by attracting more VC investment.

These findings suggest at least two directions for future studies. First, if the geocode of VC investors and investees is available, it would be interesting to study within-city transportation in detail. For a metropolitan area where within-city commuting time could not be neglected, the distance between the HSR station and VC participants might also matter. In a big city like Shanghai, the effect of HSR on a firm located at the far side of the city (opposed to the station side) differs from that on another firm located near the station. Second, this study only considers VC flows as a way of capital flow, while, in reality, other types of investments (e.g., mergers and acquisitions of companies located in different regions) also play an important role in reshaping the regional economy (Bernstein et al., 2016; Giroud, 2013; Lin, 2019). A study of the effect of HSR expansion on other means of capital flow is important for future research. Furthermore, while this study focuses on the quantity of VC investment deals, the quality could also be an interesting topic. As HSR expansion largely facilitates communication between VC investors and investees, investors can provide more value-added service to investees and promote their development.

Reference

Ahlfeldt, G. M., & Feddersen, A. (2010). From periphery to core: economic adjustments to high speed rail. *IEB Working Paper* 2010/36.

Adukia, A., Asher, S., & Novosad, P. (2020). Educational investment responses to economic opportunity: evidence from Indian road construction. American Economic Journal: Applied Economics, 12(1), 348-76.

Aldrich, H. E., & Yang, T. (2014). How do entrepreneurs know what to do? Learning and organizing in new ventures. Journal of Evolutionary Economics, 24(1), 59-82.

Andersson, D. E., Shyr, O. F., & Lee, A. (2012). The successes and failures of a key transportation link: accessibility effects of Taiwan's high-speed rail. The Annals of regional science, 48(1), 203-223.

Banerjee, A., Duflo, E., & Qian, N. (2020). On the road: Access to transportation infrastructure and economic growth in China. Journal of Development Economics, 145, 102442.

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

Baum-Snow, N., Brandt, L., Henderson, J. V., Turner, M. A., & Zhang, Q. (2017). Roads, railroads, and decentralization of Chinese cities. Review of Economics and Statistics, 99(3), 435-448.

Belke, A. H., Fehn, R., & Foster-McGregor, N. (2003). Does venture capital investment spur employment growth?.

Berger, T., & Enflo, K. (2017). Locomotives of local growth: The short-and long-term impact of railroads in Sweden. Journal of Urban Economics, 98, 124-138.

Bernard, A. B., Moxnes, A., & Saito, Y. U. (2015). Production networks, geography and firm performance (No. w21082). National Bureau of Economic Research.

Bernstein, S., Giroud, X., & Townsend, R. R. (2016). The impact of venture capital monitoring. The Journal of Finance, 71(4), 1591-1622.

Coto-Millán, P., Inglada, V., & Rey, B. (2007). Effects of network economies in high-speed rail: the Spanish case. The Annals of Regional Science, 41(4), 911-925.

Cumming, D., & Dai, N. (2010). Local bias in venture capital investments. Journal of Empirical Finance, 17(3), 362-380.

Chen, H., Gompers, P., Kovner, A., & Lerner, J. (2010). Buy local? The geography of venture capital. Journal of Urban Economics, 67(1), 90-102.

Donaldson, D. (2018). Railroads of the Raj: Estimating the impact of transportation infrastructure. American Economic Review, 108(4-5), 899-934.

Dong, X. (2018). High-speed railway and urban sectoral employment in China. Transportation Research Part A: Policy and Practice, 116, 603-621.

Dong, X., Zheng, S., & Kahn, M. E. (2020). The role of transportation speed in facilitating high skilled teamwork across cities. Journal of Urban Economics, 115, 103212.

Duan, L., Sun, W., & Zheng, S. (2020). Transportation network and venture capital mobility: An analysis of air travel and high-speed rail in China. Journal of Transport Geography, 88, 102852.

Duflo, E., & Pande, R. (2007). Dams. The Quarterly Journal of Economics, 122(2), 601-646.

Duranton, G., Morrow, P. M., & Turner, M. A. (2014). Roads and Trade: Evidence from the US. Review of Economic Studies, 81(2), 681-724.

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

Faber, B. (2014). Trade integration, market size, and industrialization: evidence from China's National Trunk Highway System. Review of Economic Studies, 81(3), 1046-1070.

Faria, A. P., & Barbosa, N. (2014). Does venture capital really foster innovation?. Economics Letters, 122(2), 129-131.

Gibbons, Stephen, and Wenjie Wu. (2017). Airports, market access and local economic performance: Evidence from China. SERC discussion paper 211.

Giroud, X. (2013). Proximity and investment: Evidence from plant-level data. The Quarterly Journal of Economics, 128(2), 861-915.

Ke, X., Chen, H., Hong, Y., & Hsiao, C. (2017). Do China's high-speed-rail projects promote local economy?—New evidence from a panel data approach. China Economic Review, 44, 203-226.

Kolmakov, V. V., Polyakova, A. G., & Shalaev, V. S. (2015). An analysis of the impact of venture capital investment on economic growth and innovation: Evidence from the USA and Russia. Ekonomski Anali/Economic Annals, 60(207).

Li, Z., & Xu, H. (2018). High-speed railroads and economic geography: Evidence from Japan. *Journal of Regional Science*, 58(4), 705-727.

Lin, X., MacLachlan, I., Ren, T., & Sun, F. (2019). Quantifying economic effects of transportation investment considering spatiotemporal heterogeneity in China: a spatial panel data model perspective. The Annals of Regional Science, 63(3), 437-459.

Lin, X., Yang, J., & MacLachlan, I. (2018). High-speed rail as a solution to metropolitan passenger mobility. *Journal of Transport and Land Use*, *11*(1), 1257-1270.

Lin, Y. (2017). Travel costs and urban specialization patterns: Evidence from China's high speed railway system. Journal of Urban Economics, 98, 98-123.

Lipscomb, M., Mobarak, A. M., & Barham, T. (2013). Development effects of electrification: Evidence from the topographic placement of hydropower plants in Brazil. American Economic Journal: Applied Economics, 5(2), 200-231.

Long, Y., Zhao, H., Zhang, X., & Li, Y.. (2017). High-speed railway and venture capital investment. Economic Research Journal.

Martí Henneberg, J. (2000). Un balance del tren de alta velocidad en Francia. Enseñanzas para el caso esapañol. Ería: revista cuatrimestral de geografía, 2000, núm. 52, p. 131-143.

Martincus, C. V., Carballo, J., & Cusolito, A. (2017). Roads, exports and employment: Evidence from a developing country. Journal of Development Economics, 125, 21-39.

Niu, D., Sun, W., & Zheng, S. (2020). Travel costs, trade, and market segmentation: Evidence from China's high-speed railway. *Papers in Regional Science*. Forthcoming.

Persson, T., & Tabellini, G. (2007). The growth effect of democracy: is it heterogenous and how can it be estimated? (No. w13150). *National Bureau of Economic Research*.

Portes, R., & Rey, H. (2005). The determinants of cross-border equity flows. Journal of international Economics, 65(2), 269-296.

Pradhan, R. P., Arvin, M. B., Nair, M., Bennett, S. E., Bahmani, S., & Hall, J. H. (2018). Endogenous dynamics between innovation, financial markets, venture capital and economic growth: Evidence from Europe. Journal of Multinational Financial Management, 45, 15-34.

Pradhan, R. P., Maradana, R. P., Zaki, D. B., Dash, S., & Jayakumar, M. (2016). Nexus between venture capital and economic growth in European economic area countries: The Granger causality approach. The Journal of Developing Areas, 50(6), 1-15.

Qin, Y. (2017). 'No county left behind?' The distributional impact of high-speed rail upgrades in China. Journal of Economic Geography, 17(3), 489-520.

Samila, S., & Sorenson, O. (2011). Venture capital, entrepreneurship, and economic growth. The Review of Economics and Statistics, 93(1), 338-349.

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

Sorenson, O., & Stuart, T. E. (2001). Syndication networks and the spatial distribution of venture capital investments. American journal of sociology, 106(6), 1546-1588.

TANG, M. C., & CHYI, Y. L. (2008). Legal environments, venture capital, and total factor productivity growth of Taiwanese industry. Contemporary Economic Policy, 26(3), 468-481.

van Pottelsberghe de la Potterie, B., & Romain, A. (2004). The economic impact of venture capital (No. 2004, 18). Discussion paper Series 1/Volkswirtschaftliches Forschungszentrum der Deutschen Bundesbank.

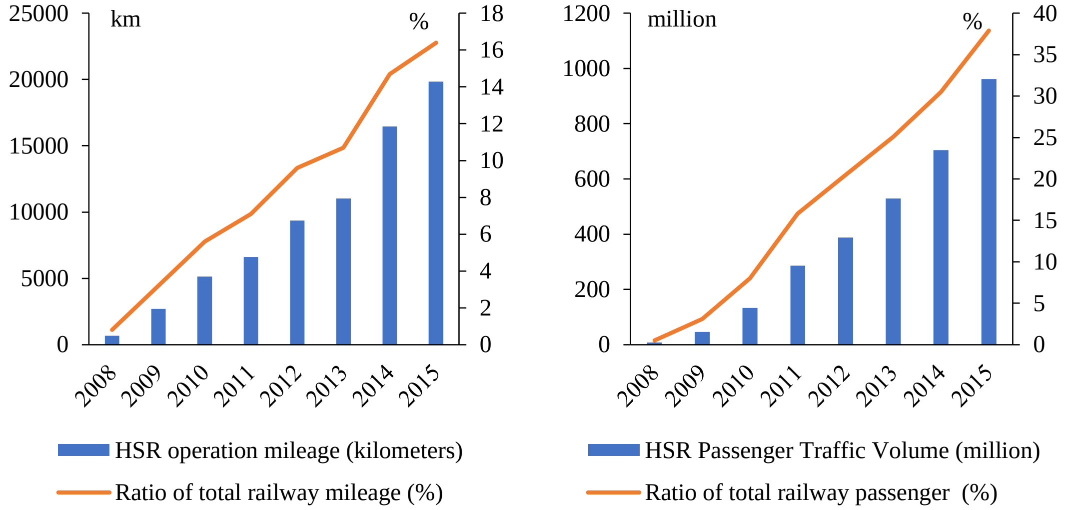
Vickerman, R. (1997). High-speed rail in Europe: experience and issues for future development. The annals of regional science, 31(1), 21-38.

Wright Robbie, M. K. (1998). Venture capital and private equity: A review and synthesis. Journal of Business Finance & Accounting, 25(5‐6), 521-570.

Yu, F., Lin, F., Tang, Y., & Zhong, C. (2019). High‐speed railway to success? The effects of high‐speed rail connection on regional economic development in China. Journal of Regional Science, 59(4), 723-742.

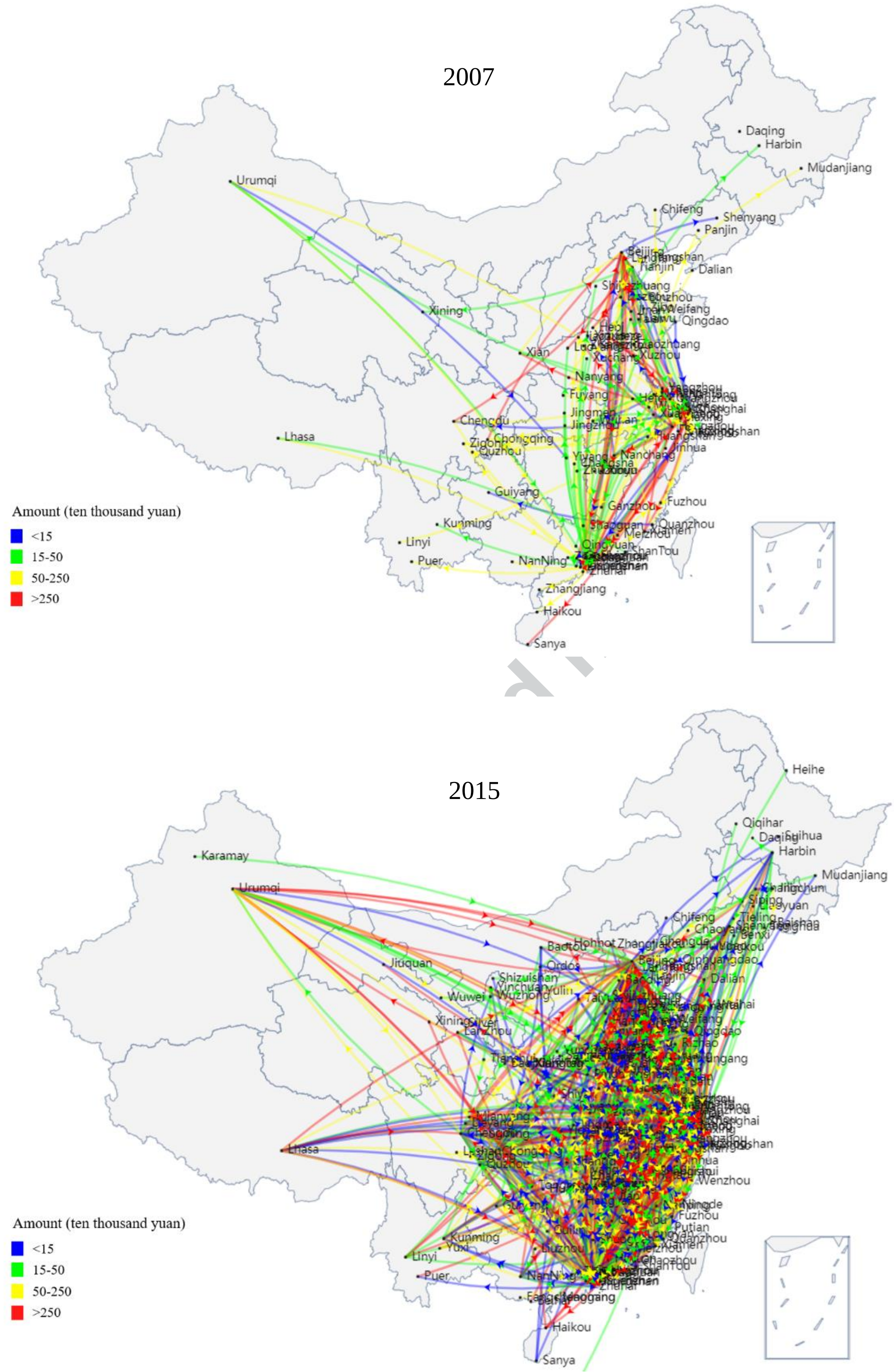
Zheng, S., & Kahn, M. E. (2013). China's bullet trains facilitate market integration and mitigate the cost of megacity growth. Proceedings of the National Academy of Sciences, 110(14), E1248-E1253.

Figure 1. The Development of High-speed Railway in China



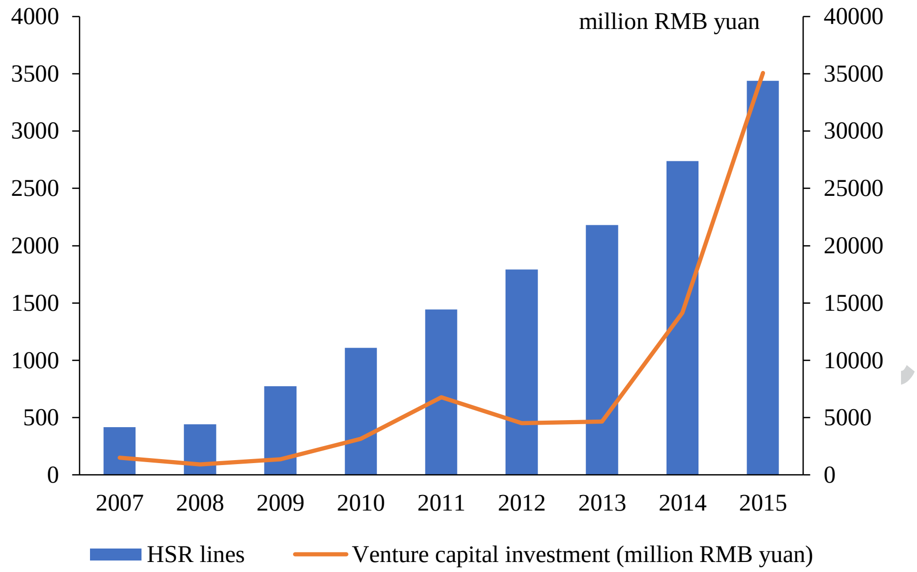
Notes: (1) The data are obtained from *China Statistical Yearbook.* (2) The left panel presents the dynamics of HSR operation mileage and its ratio of total railway mileage from 2008 to 2015 and the right panel presents the dynamics of HSR passenger traffic volume and its ratio of total railway passenger traffic volume from 2008 to 2015.

Figure 2. Spatial Description of Venture Capital Flow



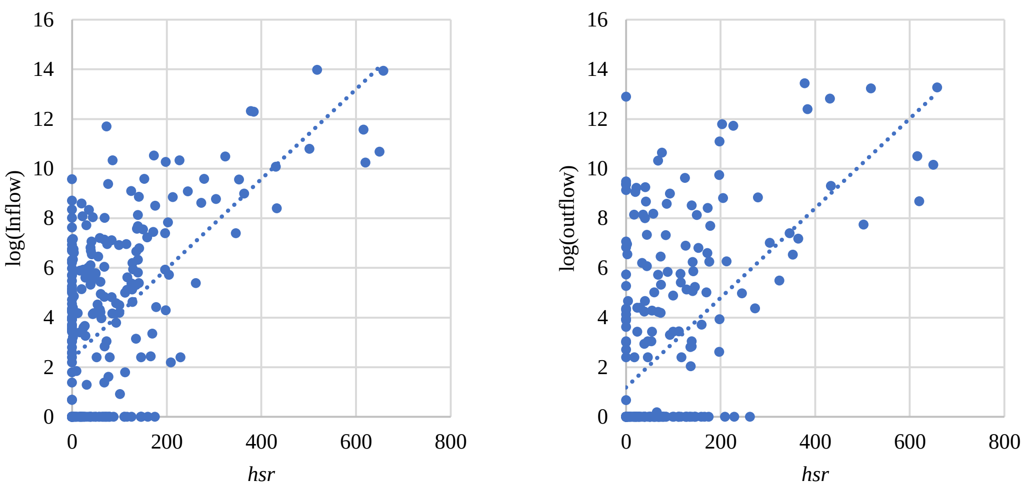
Notes: (1) VC investment data are obtained from the Zero2IPO Database. (2) The upper and lower panels indicate VC flows in 2007 and 2015, respectively. The direction of each arrow implies the VC flow direction.

Figure 3. The Relationship between HSR Construction and Venture Capital Investment



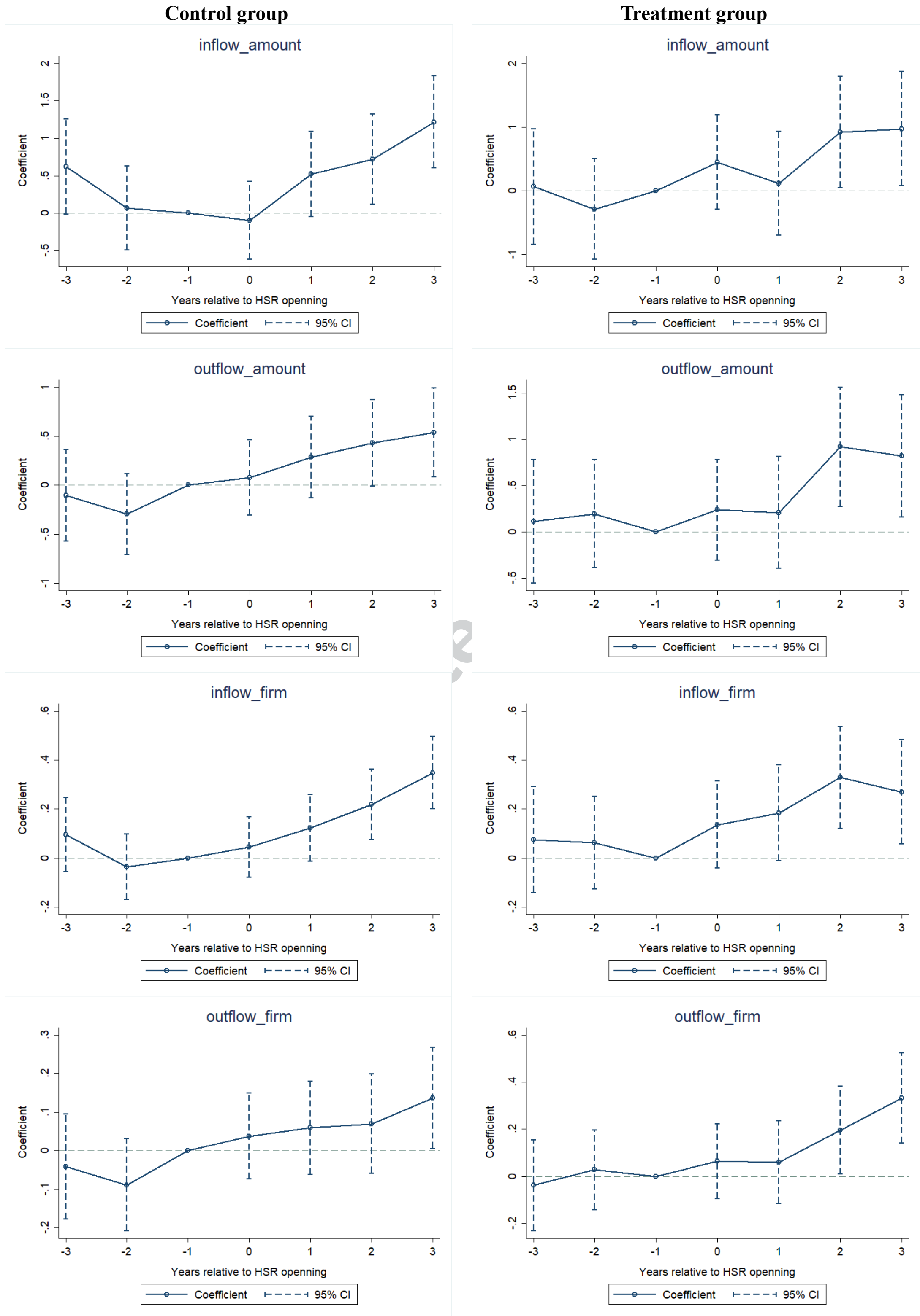
Notes: HSR data are obtained from *Train Schedule Book*, and VC investment data are obtained from the Zero2IPO Database.

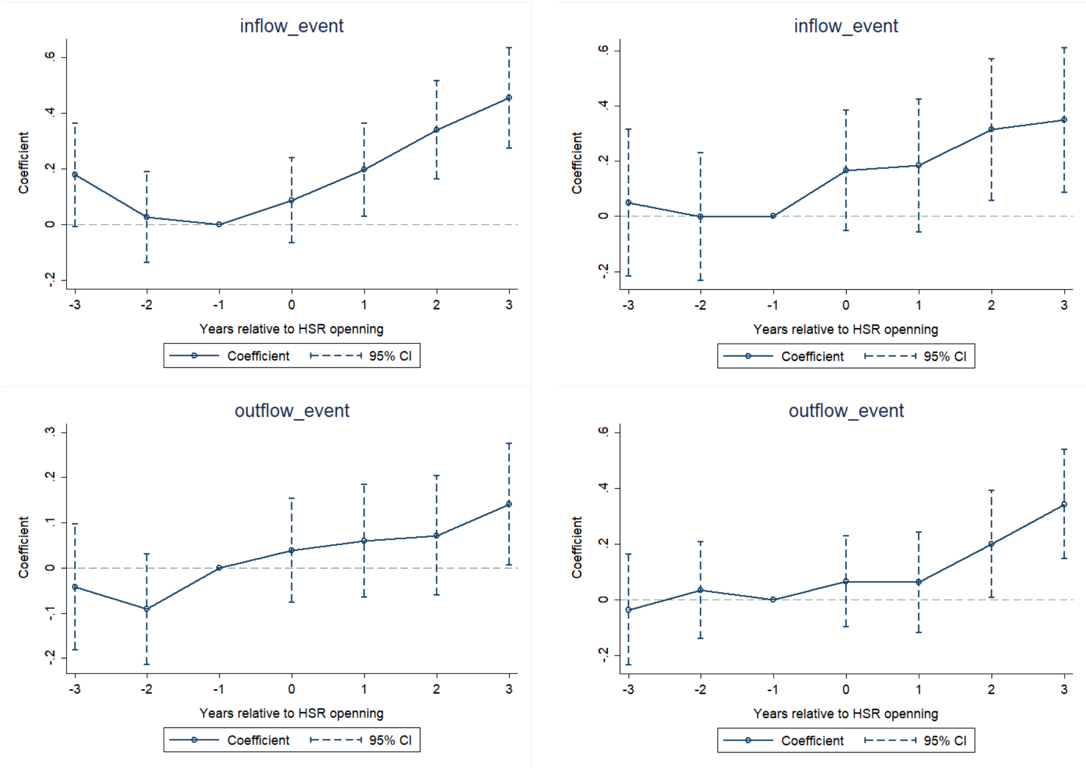
Figure 4. The HSR Measure and Venture Capital Mobility of Cities



Notes: HSR data are obtained from *Train Schedule Book*, and VC investment data are obtained from the Zero2IPO Database.

Figure 5. Heterogeneous Results: Displacement Effects versus Net Growth Effects





Notes: Figures in the left column demonstrate the parallel trends for control group, and figures in the right column demonstrate the parallel trends for treatment group.

Table 1. Summary Statistics

Variable	Definition	Obs.	Mean	Std. Dev.	Min	Max
inflow_value	The total amount of VC investment inflow (10 thousand RMB yuan)	2,520	2842.24	36356.14	0	1169017
outflow_value	The total amount of VC investment outflow (10 thousand RMB yuan)	2,520	2851.87	28269.91	0	686684.8
inflow_firm	VC inflow measured by the total number of invested companies	2,520	6.45	45.48	0	1451
outflow_firm	VC outflow measured by the total number of investee companies	2,520	7.98	65.41	0	1948
inflow_event	VC inflow measured by the total number of investment events	2,520	8.87	60.02	0	1962
outflow_event	VC outflow measured by the total number of investment events	2,520	8.93	75.03	0	2264
hsr	The number of HSR trains connecting a city	2,520	28.79	69.70	0	658
hsr_iv	The historical instrumental variable of the HSR measure	2,520	0.31	0.46	0	1
city_connect	The number of cities connected by HSR	2,520	9.70	19.27	0	127
w_hsr	The HSR measure with speed weight	2,520	23.79	60.19	0	596.67
hsr_post	Dummy variable that indicate the city is connected by HSR at that time	2,520	0.38	0.49	0	1
gdp	The gross domestic product (100 million yuan)	2,520	1766.44	2449.88	61.84	25123.45
employment	Employment (10 thousand people)	2,520	46.30	62.95	4.28	727.40
loan	Loan balance of financial institution (billion RMB yuan)	2,520	183.55	410.25	3.51	5338.72
deposit	Deposit balance of financial institution (billion RMB yuan)	2,520	277.66	689.16	6.50	12228.43
gdp3	Share of the tertiary industry's GDP (%)	2,520	36.62	8.96	8.58	79.65

Table 2. Main Results: The Effects of HSR Connection on VC Flows

	OLS		2SLS		DID	
Dependent variables:	*inflow_value*	*outflow_value*	*inflow_value*	*outflow_value*	*inflow_value*	*outflow_value*
	(1)	(2)	(3)	(4)	(5)	(6)
hsr	0.004***	0.006***	0.010**	0.016***		
	(0.001)	(0.001)	(0.003)	(0.002)		
hsr_post					0.351**	0.233**
					(0.141)	(0.117)
log(*gdp*)	-0.045	-0.093	-0.012	-0.126	-0.037	-0.080
	(0.406)	(0.301)	(0.296)	(0.312)	(0.408)	(0.304)
log(*employment*)	0.178	0.516***	-0.041	0.205	0.295	0.686***
	(0.201)	(0.149)	(0.189)	(0.169)	(0.198)	(0.148)
log(*loan*)	0.103	-0.245	0.439**	-0.124	0.054	-0.315*
	(0.230)	(0.170)	(0.205)	(0.179)	(0.230)	(0.172)
log(*deposit*)	0.230	0.489	1.135***	0.895*	0.089	0.286
	(0.607)	(0.450)	(0.339)	(0.475)	(0.608)	(0.454)
gdp3	0.003	0.016	0.016	0.008	0.006	0.020
	(0.017)	(0.013)	(0.012)	(0.013)	(0.017)	(0.013)
City FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
R^2	0.363	0.442	0.527	0.473	0.500	0.552
N	2520	2520	2520	2520	2520	2520
First-stage results						
IV			23.471***			
			(5.197)			
Kleibergen-Paap F statistic			13.510			

Notes: Robust standard errors are reported in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3. Robustness Checks: Alternative Venture Capital Measurement

Dependent variables:	*inflow_firm*	*outflow_firm*	*inflow_event*	*outflow_event*
	(1)	(2)	(3)	(4)
Panel A. Instrumental Variable Approach				
hsr	0.006***	0.007***	0.005***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.596	0.569	0.566	0.569
N	2520	2520	2520	2520
Panel B. Difference in Difference Approach				
hsr_post	0.069*	0.078**	0.152***	0.077*
	(0.040)	(0.039)	(0.047)	(0.040)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.410	0.442	0.403	0.440
N	2520	2520	2520	2520

Notes: Robust standard errors are reported in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4. Robustness Checks: Alternative HSR Measurement and Speed Weight

Dependent variables:	*inflow_value*	*outflow_value*	*inflow_value*	*outflow_value*
	(1)	(2)	(3)	(4)
city_connect	0.025***	0.038***		
	(0.008)	(0.006)		
w_hsr			0.010***	0.017***
			(0.003)	(0.003)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.526	0.353	0.527	0.467
N	2520	2520	2520	2520
First-stage results				
IV	7.600***		22.014***	
	(1.451)		(4.646)	
Kleibergen-Paap F statistic	32.843		13.158	

Notes: Robust standard errors are reported in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5. Robustness Checks: Drop Star Cities

	Remove never connected cities		Remove 35 major cities	
Dependent variables:	*inflow_value*	*outflow_value*	*inflow_value*	*outflow_value*
	(1)	(2)	(3)	(4)
Panel A. Instrumental Variable Approach				
hsr	0.016**	0.021***	0.012**	0.022***
	(0.007)	(0.005)	(0.005)	(0.004)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.534	0.475	0.358	0.252
N	1638	1638	2205	2205
First-stage results				
IV	26.537***		19.187***	
	(7.481)		(4.077)	
Kleibergen-Paap F statistic	17.850		13.694	
Panel B. Difference in Difference Approach				
hsr_post	0.361*	0.019	0.386**	0.217*
	(0.185)	(0.151)	(0.157)	(0.120)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.300	0.365	0.277	0.261
N	1638	1638	2205	2205

Notes: Robust standard errors are reported in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6. Heterogeneous Results: City Size

Dependent variables:	*inflow_value*		*outflow_value*	
	Big cities	Small cities	Big cities	Small cities
	(1)	(2)	(3)	(4)
Panel A. Instrumental Variable Approach				
hsr	0.005^{***}	0.003	0.010^{***}	0.056^{***}
	(0.001)	(0.005)	(0.003)	(0.015)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.676	0.095	0.526	0.030
N	1260	1260	1260	1260
First-stage results				
IV	27.525^{***}	7.206^{**}	27.525^{***}	7.206^{**}
	(8.786)	(2.830)	(8.786)	(2.830)
Kleibergen-Paap F statistic	12.746	5.510	12.746	5.510
Panel B. Difference in Difference Approach				
hsr_post	0.129^{**}	-0.023	0.392^{**}	0.220^{**}
	(0.062)	(0.044)	(0.199)	(0.108)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.421	0.179	0.375	0.163
N	1260	1260	1260	1260

Notes: Robust standard errors are reported in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7a. Heterogeneous Results: Industry Type

Dependent variables:	*inflow_value*			*outflow_value*		
	First industry	Second industry	Tertiary industry	First industry	Second industry	Tertiary industry
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Instrumental Variable Approach						
hsr	0.004**	0.005	0.013***	0.004***	0.010***	0.018***
	(0.002)	(0.003)	(0.002)	(0.001)	(0.002)	(0.002)
City attributes	yes	yes	yes	yes	yes	yes
City FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
R^2	0.097	0.238	0.142	0.297	0.434	0.429
N	2520	2520	2520	2520	2520	2520
Panel B. Difference in Difference Approach						
hsr_post	0.122*	-0.123	0.344***	0.130**	0.091	0.259**
	(0.068)	(0.171)	(0.116)	(0.051)	(0.110)	(0.112)
City attributes	yes	yes	yes	yes	yes	yes
City FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
R^2	0.100	0.070	0.304	0.362	0.241	0.350
N	2520	2520	2520	2520	2520	2520

Notes: Robust standard errors are reported in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7b. Heterogeneous Results: Industry Type

Dependent variables:	*inflow_value*		*outflow_value*	
	High-tech industry	Non-high-tech industry	High-tech industry	Non-high-tech industry
	(1)	(2)	(3)	(4)
Panel A. Instrumental Variable Approach				
hsr	0.017***	0.001	0.018***	0.012***
	(0.002)	(0.003)	(0.002)	(0.002)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.410	0.072	0.464	0.336
N	2520	2520	2520	2520
Panel B. Difference in Difference Approach				
hsr_post	0.367***	-0.220	0.281***	0.098
	(0.115)	(0.180)	(0.101)	(0.124)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.314	0.024	0.364	0.002
N	2520	2520	2520	2520

Notes: Robust standard errors are reported in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 8. Heterogeneous Results: Investment Size

Dependent variables:	*inflow_value*		*outflow_value*	
	Small investment	Large investment	Small investment	Large investment
	(1)	(2)	(3)	(4)
Panel A. Instrumental Variable Approach				
hsr	0.013***	0.007***	0.017***	0.007***
	(0.004)	(0.002)	(0.003)	(0.002)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.478	0.523	0.444	0.468
N	2520	2520	2520	2520
Panel B. Difference in Difference Approach				
hsr_post	0.606***	0.409***	0.386***	0.219***
	(0.167)	(0.101)	(0.128)	(0.076)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.263	0.334	0.344	0.366
N	2520	2520	2520	2520

Notes: Robust standard errors are reported in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 9. Heterogeneous Results: Development Stage of the Invested Company

Dependent variables:	*inflow_value*		*outflow_value*	
	Young firms	Mature firms	Young firms	Mature firms
	(1)	(2)	(3)	(4)
Panel A. Instrumental Variable Approach				
hsr	0.013***	0.005	0.015***	0.014***
	(0.002)	(0.003)	(0.002)	(0.002)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.451	0.265	0.284	0.474
N	2520	2520	2520	2520
Panel B. Difference in Difference Approach				
hsr_post	0.218**	0.244	0.163*	0.146
	(0.110)	(0.175)	(0.094)	(0.128)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	0.474	0.282	0.355	0.375
N	2520	2520	2520	2520

Notes: Robust standard errors are reported in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 10. Heterogeneous Results: Extensive Margins versus Intensive Margins

Dependent variables:	*inflow_value*		*outflow_value*	
	Intensive margins	Extensive margins	Intensive margins	Extensive margins
	(1)	(2)	(3)	(4)
Panel A. Instrumental Variable Approach				
hsr	0.012***	0.012	0.015***	0.027***
	(0.003)	(0.009)	(0.002)	(0.005)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	810	1710	333	2187
N	0.469	0.196	0.315	0.158
First-stage results				
IV	45.340***	10.225***	58.311**	12.043***
	(11.880)	(3.621)	(27.569)	(3.021)
Kleibergen-Paap F statistic	12.604	11.443	26.609	14.347
Panel B. Difference in Difference Approach				
hsr_post	0.782***	0.288	0.796*	0.724***
	(0.266)	(0.181)	(0.457)	(0.120)
City attributes	yes	yes	yes	yes
City FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
R^2	810	1710	333	2187
N	0.415	0.185	0.585	0.031

Notes: Robust standard errors are reported in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 11. Heterogeneous Results: Displacement Effects versus Net Growth Effects

Dependent variables:	*inflow_value*	*outflow_ value*	*inflow_firm*	*outflow_firm*	*inflow_event*	*inflow_event*
	(1)	(2)	(3)	(4)	(5)	(6)
before4	-0.228	-0.353**	-0.111*	-0.166***	-0.067	-0.166***
	(0.238)	(0.175)	(0.057)	(0.051)	(0.070)	(0.052)
before3	0.623*	-0.107	0.096	-0.042	0.178*	-0.042
	(0.324)	(0.238)	(0.077)	(0.069)	(0.095)	(0.071)
before2	0.067	-0.296	-0.036	-0.088	0.026	-0.092
	(0.285)	(0.209)	(0.068)	(0.061)	(0.084)	(0.063)
post0	-0.095	0.076	0.044	0.038	0.087	0.039
	(0.266)	(0.195)	(0.063)	(0.057)	(0.078)	(0.058)
post1	0.523*	0.285	0.122*	0.059	0.197**	0.060
	(0.290)	(0.213)	(0.069)	(0.062)	(0.085)	(0.064)
post2	0.721**	0.430*	0.218***	0.070	0.340***	0.071
	(0.307)	(0.226)	(0.073)	(0.066)	(0.090)	(0.067)
post3	1.217***	0.538**	0.348***	0.137**	0.454***	0.140**
	(0.313)	(0.230)	(0.075)	(0.067)	(0.092)	(0.069)
post4	1.313***	0.661***	0.400***	0.206***	0.488***	0.218***
	(0.244)	(0.179)	(0.058)	(0.052)	(0.072)	(0.053)
before4×treated	-0.237	-0.306	0.010	-0.075	-0.041	-0.083
	(0.342)	(0.251)	(0.082)	(0.073)	(0.100)	(0.075)
before3×treated	0.065	0.113	0.075	-0.038	0.050	-0.035
	(0.462)	(0.339)	(0.110)	(0.099)	(0.135)	(0.101)
before2×treated	-0.284	0.198	0.062	0.027	-0.001	0.034
	(0.403)	(0.296)	(0.096)	(0.086)	(0.118)	(0.088)
post0×treated	0.450	0.239	0.136	0.064	0.165	0.065
	(0.378)	(0.278)	(0.090)	(0.081)	(0.111)	(0.083)
post1×treated	0.118	0.210	0.184*	0.060	0.183	0.062
	(0.417)	(0.306)	(0.099)	(0.089)	(0.122)	(0.091)
post2×treated	0.920**	0.919***	0.329***	0.196**	0.314**	0.200**
	(0.446)	(0.327)	(0.106)	(0.095)	(0.131)	(0.098)
post3×treated	0.975**	0.820**	0.270**	0.331***	0.349***	0.343***
	(0.456)	(0.335)	(0.109)	(0.097)	(0.134)	(0.100)
post4×treated	0.975***	1.043***	0.314***	0.377***	0.344***	0.379***
	(0.366)	(0.269)	(0.087)	(0.078)	(0.108)	(0.080)
City attributes	yes	yes	yes	yes	yes	yes
City FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes

N	2844	2844	2844	2844	2844	2844
R^2	0.469	0.554	0.606	0.642	0.571	0.639

Notes: Robust standard errors are reported in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.