High-speed rail and the spatial pattern of new firm births: Evidence from China

Zheng Chang[a], Longfei Zheng[b]

[a] Corresponding Author
Taubman Center for State and Local Government, Kennedy School of Government, Harvard University
Institute of Science, Technology and Policy, ETH Zurich.
E-mail address: zchang@hks.harvard.edu

[b] Longfei Zheng
Hang Lung Center for Real Estate and Department of Construction Management
Tsinghua University, Beijing, China

Abstract

This study examined the impact of high-speed rail (HSR) on the spatial patterns of the new firm births in China. Through a set of difference-in-differences regressions, we found that agglomeration economies and HSR access each play an important role in determining the spatial pattern of the birth of new firms. Overall, the number of new firms declined significantly in counties with HSR access. However, the average effect masks significant heterogeneity with respect to industry type and geographic location. More firms in the service sector cluster in urban districts due to HSR, while firms in the primary and manufacturing sectors move out to locations without HSR access. Among four Chinese regions, central China attracts the most firms, while the underdeveloped western and northeastern regions are less successful. These results suggest that the development of an HSR network increases regional inequality. We show that people find districts with HSR attractive, which boosts the demand within the service sector. However, population concentration can raise land cost, as the primary and manufacturing sectors are crowded out to other, less expensive locations. This study demonstrates that a grasp of firm movement patterns is critical to understanding how HSR reshapes the spatial distribution of economic activities.

Keywords: High-speed rail, new firm birth, difference-in-differences regression, agglomeration economics, China

1. Introduction

Where private firms choose to locate is determined intrinsically by the trade-off between the benefits and costs of a location. A location may have different revenue and cost implications depending on the type of firm. Firms that produce tradable goods, such as manufactured products, ship and sell the products in regional, national, and global markets. In the case of tradable goods, a specific location does not have a significant influence on firms' revenue generation. Thus, the location choice is largely driven by cost minimization. For example, manufacturing firms and other firms that produce tradable goods are often located far away from the city center in locations where the land and labor costs are relatively low. In contrast, the location choice of firms that provide non-tradable goods, including service businesses such as hair salons and restaurants, is largely driven by revenue maximization. Firms in the service sector often cluster in urban areas where market demand is relatively high.

A notable phenomenon is that firms are more likely to be located in a market with an existing cluster of firms from the same industry. This finding can be explained by agglomeration economics, which refers to the benefits or cost reduction from the spatial concentration of firms and people (Puga, 2010). Scholars have highlighted three channels of agglomeration benefits: input sharing, labor-market pooling, and knowledge spillover (Duranton and Puga, 2004; Marshall, 1920; Rosenthal and Strange, 2004). Different mechanisms are relevant to different industries. For manufacturing firms, the input–output linkage is a critical channel for industrial agglomeration; many studies have documented the co-agglomeration pattern of manufacturing firms (Diodato et al., 2018; Ellison et al., 2010). For firms in the service sector, labor-market pooling and knowledge spillover channels are more relevant for their clustering. These firms value a rich information environment in larger cities, and urban diversity promotes innovation through cross-fertilization (Arzaghi and Henderson, 2008; Jacob, 1969). Accordingly, firms in the service sector prefer to establish themselves in large cities where they experience productivity gains from labor-market pooling and knowledge spillover.

Another factor affecting firm location is the degree of accessibility and connectivity to other districts, which is largely determined by the transportation system. A well-functioning transportation network can reinforce agglomeration benefits by improving accessibility (Krugman, 1991). Studies have shown that transportation development can stimulate inter-city trade, promote economic growth, reduce the price gap, and facilitate innovation by reducing the cost of knowledge spillover (Agrawal et al., 2017; Donaldson and Hornbeck, 2016; Duranton and Turner, 2012). Accordingly, the transportation system can have a substantial influence on a firm's location decision. By connecting urban and rural districts, firms may rebalance the trade-off between the high revenue and high cost of urban districts and the low revenue and low cost of suburban areas. The theoretical prediction of the new spatial equilibrium due to transportation development is not transparent because multiple equilibria exist, and the comparative statics depend on the parameter values (Fujita and Ogawa, 1982). However, many empirical studies suggest that road and highway construction decentralize a region's population as well as the manufacturing industry, drawing them to suburban areas far away from the city center (Baum-Snow, 2007; Baum-Snow et al. 2017).

Among all road commuting techniques, the high-speed railway (HSR) is unique because it carries people rather than cargo and operates at a significantly faster speed than highways and conventional railways. China has built the world's largest HSR network in the past decade. There is a growing body of literature estimating the socioeconomic impact of HSR, including economic growth, accessibility, housing market changes, and environmental sustainability (Chang and Diao, 2021; Chang et al., 2021a; Chen et al., 2019; Zheng et al., 2019). Empirical studies have found that HSR stimulates workers' mobility and reinforces agglomeration benefits (Ahlfelt and Feddersen, 2018; Heuermann and Schmieder, 2019). HSR is particularly important in stimulating non-tradable goods consumption and promoting knowledge spillover by facilitating human interaction (Dong et al., 2020; Lin, 2017). However, other evidence suggests that HSR has a significant redistribution effect and favors the development of larger cities at the expense of small vicinal cities (Qin, 2017; Zheng et al., 2019). The evidence suggests that more people are moving from small or less-developed regions to large cities to take advantage of emerging opportunities and amenities (Chang, 2021).

As the economic growth of cities is largely dependent on the performance of firms located in or around them, one way to understand the impact of HSR on urban growth and the redistribution effect among cities is to explore how firms respond to HSR shocks. Several studies have identified the relationship between HSR and firm location choice in European countries using the stated choice experiment, yet the conclusion is case-dependent (Beckerich et al., 2017; Willigers and Wee, 2011). In general, cases drawn on medium and small size of cities do not find much effect of HSR on firm location choice (Beckerich et al., 2017). In China, studies examined the impact of HSR on the pattern of urban specialization by employing the urban employment statistics (Dong, 2018; Lin, 2017; Shao et al., 2018). These studies, which applied the difference-in-differences (DID) method, cover similar time periods; while they concluded that HSR promoted urban specialization and industrial concentration, their findings are not consistent on which sectors grew the most.[1] Chang et al. (2021b) challenged these studies by pointing out that local governments frequently changed the standard of urban employment statistics, and scholars should be very careful when employing such data. As an alternative, they leveraged firm-level statistics and examined the impact of HSR on the spatial pattern of firm relocation in China's Greater Bay Area (GBA). They found that HSR induced the decentralization of manufacturing industry and concentration of service industry in GBA. Zhou and Zhang (2021) studied the impact of HSR on industrial development in two core-periphery city pairs (Shanghai–Suzhou and Beijing–Langfang) in China. They found that the service industrial park economy, including housing prices, grew faster with HSR access, while the economy and housing price premium grew slower for manufacturing industrial park. Their findings implicitly indicated the HSR played different roles in the growth of manufacturing and service industries.

In sum, existing studies have examined the impact of HSR on firm/industry agglomeration and growth in China. However, those studies either focus on a specific region, such as China GBA, or show inconsistent results from urban employment statistics. A comprehensive study to evaluate the causal impact of HSR on firms on a national scale is necessary and important. To explore the causal impact of HSR on the spatial distribution of firms, the present study focuses on the birth pattern of new firms rather than on firm relocation as Chang et al. (2021b) did. Firm relocation may be constrained by sunk costs, such as previous investment in capital, land, and labor. The advantage of studying new firms is that their location choice is largely unconstrained by previous decisions. Investors choose locations to maximize profit and consider the existing business environment to be exogenous. Thus, new firms' location choice is largely driven by the trade-off between existing agglomerations and improved accessibility in districts connected to HSR networks.

In this study, we employed firm registration data in China from 2004 to 2016 and estimated the impact of HSR expansion on the number of new firm establishments at the county level. Using DID estimation, we found that existing business agglomerations play a significant role in attracting new firms. The elasticity of the number of new firms to existing firms is approximately 0.52. After controlling for existing firms, our baseline results showed that the number of new firms declined by approximately 6.2% for counties connected to HSR networks. However, the average effect masks substantial heterogeneity for firms in different sectors and regions. Further investigation indicated a robust pattern for the concentration of the service sector in urban districts and the decentralization of primary and manufacturing sectors. Of China's four geographic regions, we found that central China was extremely attractive to new firms due to its HSR access, while the underdeveloped western and northeastern regions were less attractive. To understand the mechanisms behind these developments, we explored population and land-price change responses to HSR access. We found that the patterns of population concentration and land price appreciation may explain the location choice of firms across different sectors.

[1] Dong (2018) found that HSR enhanced the growth of retail and hotel sectors while other sectors remained unaffected. Shao et al. (2018) found HSR promoting the growth of IT and finance, rather than retail and hotel sectors. Lin (2017) found the growth of the service sector driven by HSR to be lower than of manufacturing and construction.

Our study makes several contributions to the literature, primary among them being it is the first study to comprehensively examine the causal impact of HSR to the spatial patterns of new firm births in the national scale in China, which fills the gap in the literature. We show that market integration due to travel cost reduction influences the birth of new firms. Second, this study contributes to the literature on agglomeration economics. Both theory and empirical evidence suggest that firms are more likely to be located in places with an existing cluster of similar firms (Artz et al, 2016), the primary reason for which is agglomeration economies. Our results reconfirm that agglomeration economies play a leading role in inducing firm establishment, and this effect applies to all types of firms across regions. Third, existing studies have shown the impact of HSR on economic growth and redistribution in cities. However, economic growth is fundamentally determined by firm activity. Our study indicates that understanding the birth pattern of new firms can partially explain the spatial pattern of economic growth and the redistribution effect. Finally, our study contributes to the literature on the impact of transportation on regional inequality. Many studies have documented how transportation networks impact, and are caused by, imbalanced regional development (Baum-Snow et al., 2020). Our results show that counties in the central and eastern coastal regions of China with HSR access gain more services but lose agriculture and manufacturing. However, counties in the underdeveloped western and northeastern regions lose all sectors after HSR. Our results are relevant to existing studies and enrich the knowledge of the role of transportation infrastructure in regional inequalities.

The remainder of this paper is organized as follows. Section 2 describes HSR development in China. Section 3 introduces the study's empirical framework and dataset. Section 4 presents the empirical results. Section 5 discusses a number of heterogeneities. Section 6 explains the firm-establishment pattern, and Section 7 concludes.

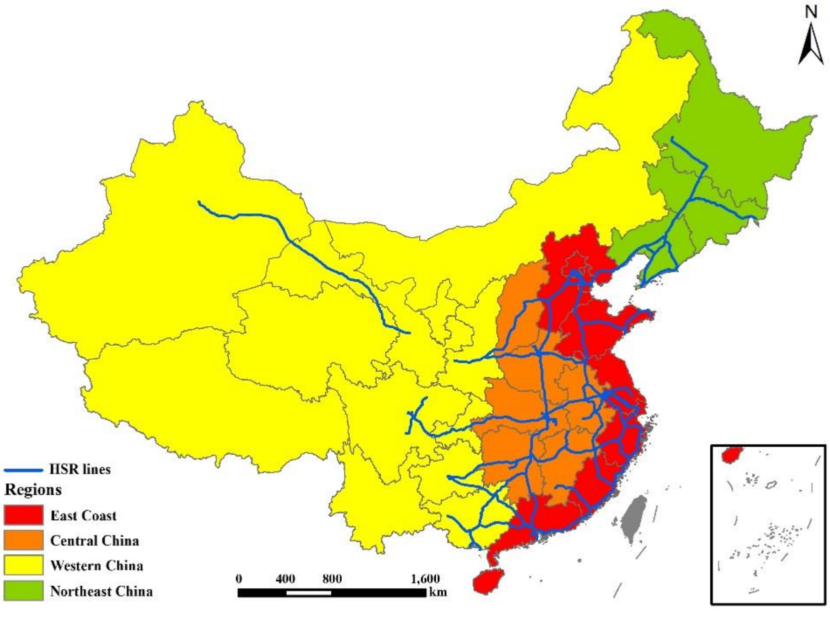
2. High-speed railway development in China

HSR is an efficient and comfortable mode of transportation popularly used for short- and medium-distance travel across cities (Yu et al., 2019). There is no universal definition for HSR; however, typically a new railway system running at speeds faster than 250 km/h is considered HSR (International Union of Railway, 2018). According to this definition, the first HSR line in China was in operation in 2008. By the end of 2020, China had built a 38,000-km HSR network, accounting for more than two-thirds of the world's HSR networks. This remarkable development was motivated by three factors (Chang, 2021). First, the railway system supports China's economic development; increasing travel speed is likely to reinforce the agglomeration economy's advantages and advance urban development. Second, conventional rail travel had reached its capacity to meet the increasing travel demand resulting from economic growth and urbanization. Since 1990, the railways had also been steadily losing customers to airlines and the expanding national expressways. The development of HSR was expected to improve train service quality and augment capacity to meet rail travel demand (Cheng and Chen, 2021). Third, developing a mega HSR network was used as a strategy to stimulate economic growth, a legacy from the 2008 global financial crisis when the Chinese government launched an RMB 4-trillion stimulus package for infrastructure.

The development of the four vertical and four horizontal high-speed railway passenger transport network (4+4 network) was initiated by the State Council in 2004 to build a 12,000-km HSR network by 2020. The backbone of this ambitious plan was eight high-speed corridors—four vertical corridors running north to south and four horizontal ones running east to west. These corridors are designated for passenger travel only and are newly built tracks that accommodate train speeds of 250–350 km/h. The 4+4 development plan was revised and extended to 16,000 km in 2008. With impressive speed, the 4+4 network was completed by the end of 2015, five years ahead of schedule. In 2016, the State Council initiated a new HSR development plan to build a 38,000-km HSR network by 2025 (National Railway Administration of China, 2016). The 4+4 network was reorganized further into eight vertical and eight horizontal corridors (8+8 network).[2] The new plan aims to connect all cities with a population of more than 500,000 to their corresponding provincial capital cities. The travel time between adjacent megacities was targeted to be 3–4 hours, and the travel time between cities within the same city cluster, 1–2 hours. The new round enjoys even faster speeds and a broader scale.

Today, a nationwide HSR network has formed with megacities at its centers and provincial capitals as critical nodes. One characteristic of China's HSR is that it serves both developed and underdeveloped regions. Figure 1 presents the HSR network across four Chinese regions as it was in 2016. As the Figure shows, the HSR network connects to all regions, promoting balanced development across the four regions, one of the initial objectives of HSR development. The network has become a popular inter-city commuting mode, providing safe, comfortable, and efficient passenger transportation services for Chinese residents. Travel costs have been reduced significantly. For example, in the 1990s, the fastest train from Beijing to Shanghai took 13.8 hours and the cost was more than 10% of the average monthly income of Beijing residents. In 2016, the same trip by HSR took only 4.5 hours and the cost was approximately 7% of the monthly income.[3] Due to decreasing travel times and affordable prices, HSR has become a preferred technology for facilitating inter-city transportation; it has strengthened market integration and accelerated urbanization, promoting economic growth.

Figure 1. The HSR network in China, 2016



Note: This figure shows the HSR network across four Chinese regions in 2016. It does not show HSR lines in Hainan and Taiwan.

3. Empirical strategy and data sources

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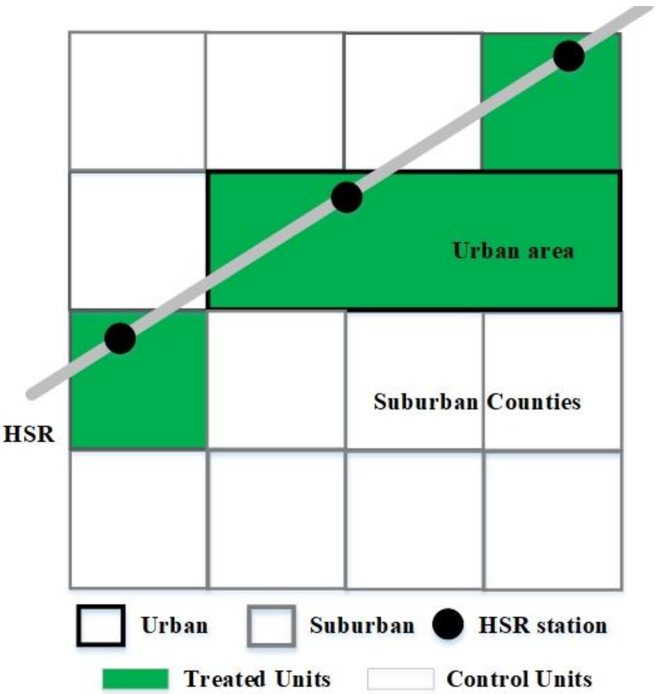
[2] The official documents on the railway development plan and the '8+8' HSR network can be found in "Medium and Long Term Railway Planning." www.nra.gov.cn/jgzf/flfg/gfxwj/zt/other/201607/t20160721_26055.shtml

[3] Income data are from the Beijing Municipal Bureau of Statistics (http://tjj.beijing.gov.cn/EnglishSite/). The ticket price was obtained from China Railway (http://www.china-railway.com.cn/).

3.1 Empirical strategy

In this study, we estimate the impact of the HSR on the spatial pattern of birth of new firms at the county level. Previous studies on Chinese expressways have defined treatment areas as cities or counties that expressway networks passed through (Faber, 2014). In contrast, HSR access hinges on the location of HSR stations. To illustrate our identification strategy, we hypothesize a scenario, in Figure 2, which shows that, while the HSR line passes through five jurisdictions, only three jurisdictions with HSR stations can be treated directly and defined as the treatment group. The remaining units are defined as the control group. In China, each city is composed of several urban and suburban counties. The prefecture government controls all urban districts directly, while suburban counties enjoy some degree of policy and fiscal autonomy. For this reason, we combined urban districts into one observation unit called the urban area.

Figure 2: Treatment VS control group



Note: This figure illustrates our identification strategy and defines the treatment and control group in DID method.

Existing studies regard HSR expansion as a quasi-natural experiment for cities (Ahlfeldt and Feddersen 2018; Chang et al., 2021a; Qin, 2017). Following previous studies on the policy effects of a quasi-experimental shock (Chang and Li, 2018; Zheng et al., 2019), we employ the standard two-way fixed-effect DID strategy to quantify the causal impact of HSR on the birth of new firms. The nearby counties in Figure 2 are classified into the control group in the baseline regression, and the model is formulated as:

$$Y_{it} = \alpha_0 + \alpha_1 HSR_{it} + \alpha_2 X_{i,t-1} + \alpha_3 Trend + \mu_i + \upsilon_t + \varepsilon_{it} \quad (1)$$

where Y_{it} is the natural logarithm of the number of new firms for county *i* in year *t*. The term HSR_{it} is a time-varying dummy variable that equals one if a county receives HSR access after year t, and zero otherwise. HSR_{it} equals the interaction of the treatment and the time dummy (treat x after) in the conventional DID model. $X_{i\,t-1}$ is a vector of socioeconomic variables, including the natural logarithm of population and GDP, lagged by one year. The term *Trend* controls for province-specific linear time trends during the study period. μ_i indicates the county-level fixed effect, and υ_t is the year fixed effect. ε_{it} is a random error. The coefficient α_1 is the focus of our research. To address the spatial and serial correlation of the outcome variable within a county, standard errors are clustered at the county level.

3.2 Data and summary statistics

Our study covered approximately a decade, from 2004 to 2016. The data used in this study were obtained from four sources. County-level economic and demographic data were collected from multiple Chinese Statistical Yearbooks. Many variables, such as wage and employment at the county level, were not available for multiple counties; therefore, we used annual GDP and population as the primary indicators in this study. The second dataset was composed of firm location data from the firm registration database of the State Administration for Market Regulation (http://wsdj.samr.gov.cn/saicmccx/). This dataset included all firm information, such as name, firm type shown by two digital industrial codes, date of registration, and location. The study was interested primarily in the primary, manufacturing, and service sectors (including nine major service sectors) but our data did not include sectors such as energy, mining, and public agencies. Based on the date of registration and location of registered firms, we aggregated the individual firm registration data with county-level data, including the annual total number of firms and the number of new firms by sector. The third dataset was the annual HSR network; we obtained the names of HSR stations from multiple railway train-schedule yearbooks. We also used Baidu Baike to search for the operation status for each station and geocoded those stations. Our data excluded Hainan, Taiwan, Hong Kong, and Macau, as those regions are not well integrated with the HSR network for geographical and political reasons. After compiling the HSR and jurisdiction data, we had 2069 counties for analysis—423 counties (or 20.4%) had HSR access in 2016, including 150 urban area and 273 suburban districts. The last dataset concerned land prices for residential and service land use. We obtained all parcel-level land transactions from www.landchina.com. Each transaction included information on location, land-use type, size, transaction date, price, and more. We calculated the annual average transaction prices of residential and service land use at the county level. Table 1 presents the variable definitions and the summary statistics.

Table 1 is organized into three panels. Panel A shows the average number of new and existing firms in each county. Both numbers are relatively high for counties with HSR access compared to counties without HSR access. Urban districts have more firms than suburban districts. Panel B presents statistics on population, GDP, and the average land price for residential and service land use. Again, these numbers are relatively high in urban districts and regions connected to HSR compared to other areas. Panel C summarizes statistics for a number of independent variables, including the time-varying treatment dummy and nearby groups.

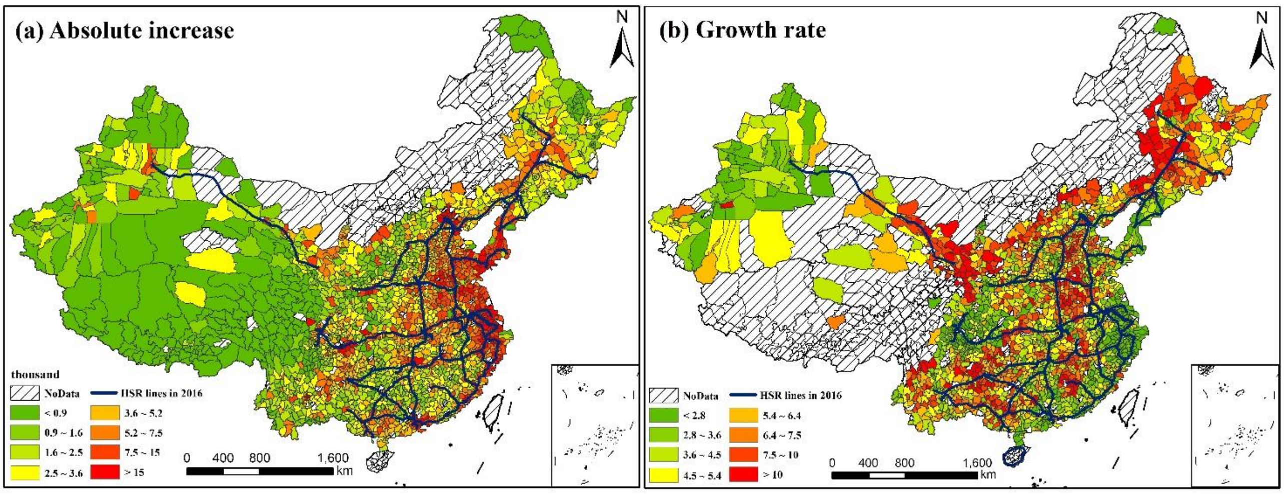
Before discussing the empirical examination, we present the stylized facts on the relationship between HSR extension and the spatial pattern of new firm births. The HSR first operated in 2008; we found growth in the number of firms from 2007 to 2016. Figure 3(a) shows the net growth in the number of firms during this period; we found that the east coast and central regions of China had the most significant growth. Figure 3(b) shows the growth rate defined by the net growth divided by the total number of firms in 2007. We found that the central region, particularly the area between two vertical HSR corridors, experienced extraordinary growth. In contrast, the east coast had a relatively low growth rate compared to other locations. This pattern suggests that new firms prefer to locate in the inland central region and that HSR is likely to influence the spatial pattern of new firm births. The next section explores the causal effect of HSR on firm establishment using regression analysis.

Table 1: Variable definition and summarized statistics

Variable	Description	Mean and standard deviation				
		Full Sample	With HSR	Without HSR	Urban	Suburban
Panel A: Firm number						
New firm	Number of new established firms	754.25	2365.82	350.37	3412.66	352.36
		(4610.38)	(10001.79)	(838.07)	(12228.45)	(799.05)
Existing firm	Number of existing firms	4531.59	14686.13	1986.77	20525.94	2113.63
		(26003.4)	(56320.4)	(4301.87)	(68706.17)	(4519.08)
Panel B: Economic outcomes and population						
GDP	Gross Domestic Product (billion yuan)	22.2	63.94	11.47	91.57	11.61
		(83.7)	(175.63)	(17.85)	(212.72)	(17.99)
Pop	Number of permanent residents (thousand)	616.3	1077.63	497.75	1396.32	497.23
		(787.14)	(1491.21)	(372.42)	(1784.09)	(348.37)
Land_Price_Resi	Unit price of residential land (Yuan/m2)	1436.05	2207.27	1199.2	2299.43	1270.53
		(1956.42)	(3050.9)	(1380.67)	(3115.16)	(1590.96)
Land_Price_Service	Unit price of service land (Yuan/m2)	1163.42	1832.87	957.61	2060.09	984.93
		(2375.21)	(4018.09)	(1494.45)	(4599.31)	(1537.25)
Panel C: HSR status						
HSR	Dummy, 1 for regions after operation of HSR, 0 otherwise	0.062	0.303	0	0.187	0.043
		(0.241)	(0.46)	(0)	(0.39)	(0.203)
Nearby	Dummy, 1 for regions without operated HSR but sharing a border to regions with operated HSR, 0 otherwise	0.122	0.0538	0.139	0.0542	0.132
		(0.327)	(0.226)	(0.346)	(0.226)	(0.339)
Observation	Number of observations	26897	5499	21398	3562	23335

Notes: Standard deviations are in parenthesis. Time trends and county and year fixed effect are not included.

Figure 3. The spatial distribution of firm growth from 2007 to 2016



Note: Due to the lack of data, the county of Inner Mongolia is not included in the analysis. In the figure 3(b), the Growth rate= (Plant Stock in 2016/ Plant Stock in 2007)-1. In order to avoid the extremely large growth rate due to the small value of denominator, we set a threshold for the 2007 plant stock. Counties won't be included in the figure 3(b) if their 2007 plant stock was lower than 100.

4. Baseline results

4.1 Baseline estimation

Table 2 summarizes the DID baseline results from employing equation (1), where the dependent variable is the natural logarithm of the number of new firms in each county. All regressions were controlled for county and year fixed effects, and standard errors were clustered at the county level. Column (1) shows that the number of newly established firms declined by approximately 15.4% after a county was connected to the HSR network. The result is statistically significant at the 1% level, and the model fits the data reasonably well with an R^2 of approximately 0.83. As counties in different provinces may have differential growth trajectories with respect to the outcome variable, we added provincial linear trends as a control variable in column (2), and the results were largely similar to the previous results. In column (3), we added socioeconomic variables as controls, including the natural logarithms of lag-1 year population and GDP, and we obtained similar results. The first three columns do not incorporate the effects of agglomeration economies on new firm births. As new firms are more likely to choose locations where there are others from the same industry, we used the natural logarithm of lag 1-year existing firms to capture the effect of industrial agglomeration. The assumption was that the spatial pattern of new firm births is affected by both existing industry cluster and HSR access. Column (4) shows that the number of new firms declined by approximately 6.2% after considering industrial agglomeration. Not surprisingly, the coefficient on existing firms was significantly positive, with an elasticity of approximately 0.52. Again, the results were robust, with an R^2 of approximately 0.84.

Table 2: Baseline DID regression results

	DID				PSM-DID			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HSR	-0.154***	-0.146***	-0.13***	-0.0617***	-0.211***	-0.196***	-0.165***	-0.0553***
	(0.0191)	(0.019)	(0.0185)	(0.0155)	(0.0235)	(0.0227)	(0.0225)	(0.0205)
Lag.GDP			0.139***	0.0403*			0.185***	0.0771**
			(0.0263)	(0.0231)			(0.0465)	(0.0367)
Lag.Pop			0.0538	0.0346			-0.0951	-0.0657
			(0.0448)	(0.0356)			(0.0781)	(0.0598)
Lag.Existing firm				0.524***				0.577***
				(0.021)				(0.0395)
County fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province linear trend	No	Yes	Yes	Yes	No	Yes	Yes	Yes
R2	0.827	0.828	0.825	0.84	0.824	0.824	0.822	0.843
Observation	26728	26728	24672	24672	9958	9958	9192	9192

Note: The dependent variable is the natural logarithm of number of new firms. The standard errors are reported in parentheses and clustered at county levels. *, **, and *** refers to the statistical significant at 10%, 5% and 1% respectively.

Given the concerns about substantial heterogeneities among counties in the treatment and control groups, we employed the propensity score matching (PSM) technique and reported the PSM–DID results in columns (5) to (8). The advantage of PSM was that the observations in the treatment and control groups were comparable with respect to the observed baseline covariates, which can reduce the treatment group selection bias. However, the number of observations was reduced by more than 60; scholars have found other drawbacks of PSM, such as inefficiency and model dependence (King and Nielsen, 2019). Nevertheless, the estimation from PSM–DID was largely consistent with the estimations in the previous columns, which further implies the validity of the DID estimation. In the following sections, we use the results in column (4) as the baseline estimation and explore additional patterns.

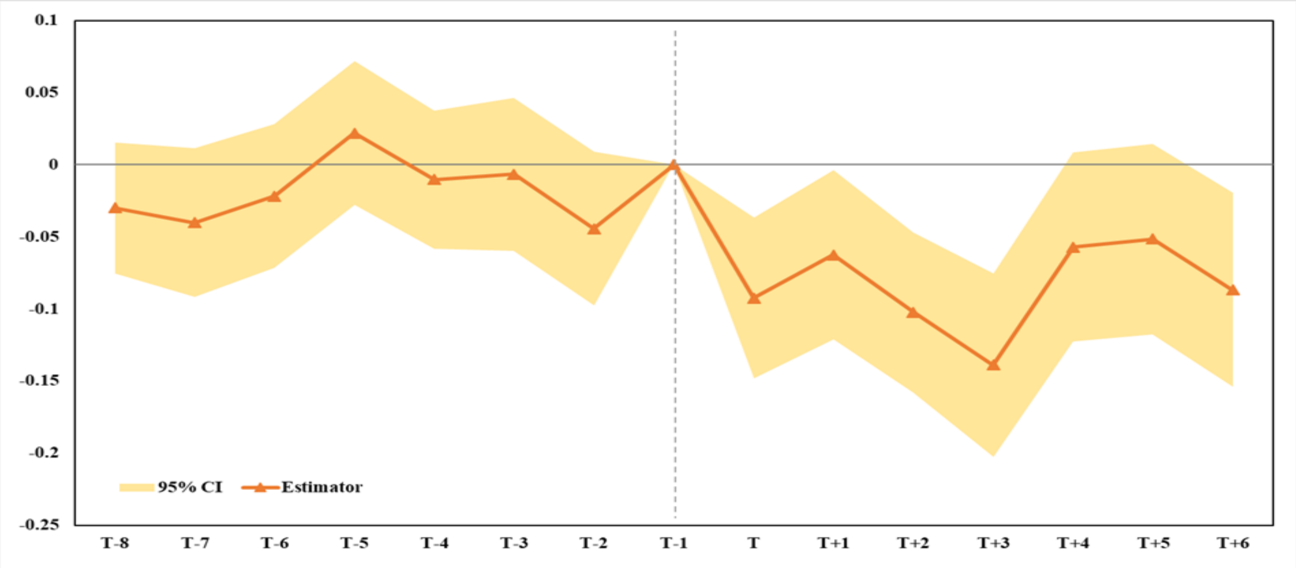
4.2 Robustness check

The baseline results demonstrate that HSR extension was significantly detrimental to affected counties because it reduced the number of new firms. The prerequisite of a DID regression is the pretreatment parallel trends assumption. To verify this assumption, we input data in the standard event-study frame, to present a graph to more clearly demonstrate the dynamics of new firm birth trends. The goal was to generate a set of lead- and lag-year indicators of actual HSR access to test if the coefficients in lead years were significantly different from zero. The model specifications were:

$$Y_{it} = b_0 + \sum_{i \neq -1} B_i HSR_i \times \mathbf{1}[i = T] + b_2 X_{i,t-1} + b_3 Trend + \mu_i + \tau_t + \varepsilon_{it} \qquad (2)$$

where $1[j = T]$ is an event-time indicator for each lead and lag year before and after HSR access. We omitted the year just before HSR (j= − -1), which was used as a reference. The coefficients in other years can be interpreted as the effect of HSR on the outcome variable relative to the reference year. All other variables remained the same as in equation (1). The coefficients with corresponding 95% confidence intervals are plotted in Figure 4. The year T is the first year of HSR implementation in each county, and we show the trends spanning 15 years.

Figure 4. Event study: The impact of HSR on the number of new firms



Note: This figure presents the coefficients of event study with corresponding 95% confidence intervals by employing the equation (2).

The results presented in Figure 4 have two implications. First, although the trends fluctuated in the pretreatment period, the coefficients in the lead years (T-8 to T-2) were not significantly different from zero relative to the reference year (T-1). This indicates that the pretreatment parallel trend assumption is valid. Second, temporal trends after HSR are shown. The trends turned downward immediately after the arrival of HSR, suggesting that counties connected to HSR become less attractive to new firms. The declining trends reached approximately 10% after connection to HSR and remained stable afterward, although the average effect was approximately 6.2% in the baseline estimation.

5. Heterogeneities

The baseline results indicate that HSR access had a significant negative impact on new firm births, which is somewhat counterintuitive. If counties with HSR access become less attractive to new firms, the affected counties must experience lower economic and employment growth. Given these undesirable consequences, why do localities lobby for an HSR station? To answer this question, the next section explores a number of heterogeneities by examining the impact between urban and suburban areas in different economic sectors and geographic regions.

5.1 Urban versus suburban

Existing studies suggest that the location of HSR stations is a key driver in determining the economic benefits of HSR (Zheng et al., 2019). If an HSR station is far away from the city center, HSR will bring minimal benefits compared to stations located closer to existing urban agglomerations. To understand the heterogeneous effect of HSR on firm births for urban and suburban districts, we interacted HSR dummies with urban and suburban indicators. The results are reported in Table 3.

Table 3: The urban and suburban disparity with spillovers

	(1)	(2)	(3)	(4)
HSR	-0.0617***		-0.0842***	
	(0.0155)		(0.0162)	
Nearby			-0.0644***	
			(0.0135)	
HSR×Urban		-0.0395**		-0.0608***
		(0.0199)		(0.0206)
Nearby ×Urban				-0.0857**
				(0.0414)
HSR×Suburban		-0.075***		-0.0988***
		(0.0204)		(0.021)
Nearby ×Suburban				-0.0633***
				(0.014)
Controls	Yes	Yes	Yes	Yes
County effects	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes
Province linear trend	Yes	Yes	Yes	Yes
R2	0.84	0.84	0.841	0.841
Observation	24672	24672	24672	24672

Note: The dependent variable is the natural logarithm of number of new firms. Other controls include the natural logarithms of lag-1 year population, GDP and plant stock. The standard errors are reported in parentheses and clustered at county levels. *, **, and *** refers to the statistical significant at 10%, 5% and 1% respectively.

Column (1) presents previous baseline results as a reference. In column (2), the overall effect is decomposed by examining the patterns in urban and suburban districts. We found that both districts were affected. Given the concern that HSR may generate spatial spillovers to nearby districts, we explored the magnitude of the spillover by interacting HSR dummies with nearby counties. Nearby counties were defined as counties without HSR access but sharing a border with the treatment group. We found that nearby counties were also affected, as shown in column (3). In column (4), we further explored the spatial spillover by location of HSR stations between urban and suburban areas. Again, we found a spillover effect.

Although parallel trends were shown through event studies, it is still possible that public sectors intentionally build HSR through locations that they believe will have more/fewer firms in the future. Suppose that HSR had no effect on firms, but planners decided that the route would pass through areas that they believed were developing quickly/slowly. Then, we might find an effect, although one does not exist. The selection of trends seems unlikely to be true because localities should prefer to have more firms rather than the reverse. However, this possibility must still be ruled out. In China, cities are classified as part of a tier system.[4] First- and second-tier cities are the most important cities in terms of economic growth and number of residents. As HSR is designed primarily to connect megacities, we ran regressions by excluding large Chinese cities; results are shown in Table 4. Columns (1) and (2) show the results by excluding all provincial capital cities in China, and columns (3) to (4) show the results by excluding the first- and second-tier cities. All results are largely consistent, which suggests that the estimation was not contaminated by the trend selection.

Table 4: Regression results by excluding large cities

	Excluding Provincial Capital Cities				**Excluding First and Second Tier Cities**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HSR	-0.0592***	-0.0816***			-0.0691***	-0.0926***		
	(0.0179)	(0.0186)			(0.0194)	(0.0201)		
Nearby		-0.0673***				-0.0725***		
		(0.0149)				(0.0152)		
HSR×Urban			-0.0333	-0.0555**			-0.0413	-0.0644**
			(0.0249)	(0.0256)			(0.027)	(0.0276)
Nearby ×Urban				-0.0867*				-0.0922**
				(0.0444)				(0.0470)
HSR×Suburban			-0.0732***	-0.0964***			-0.0844***	-0.109***
			(0.0229)	(0.0235)			(0.0251)	(0.0257)
Nearby ×Suburban				-0.066***				-0.0713***
				(0.0155)				(0.0158)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province linear trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.836	0.836	0.836	0.836	0.84	0.84	0.84	0.84
Observation	22464	22464	22464	22464	21432	21432	21432	21432

Note: The dependent variable is the natural logarithm of number of new firms. Other controls include the natural logarithms of lag-1 year population, GDP and plant stock. The standard errors are reported in parentheses and clustered at county levels. *, **, and *** refers to the statistical significant at 10%, 5% and 1% respectively.

5.2 Heterogeneities by economic sector

[4] In China, the significance of cities is reflected in a hierarchical classification, called the tier system, applied to the prefecture level. Cities are classified into six tiers depending on their political and economic status. In general, first and second-tier cities play the most important roles in China, and all of these are major HSR terminals.

Next, we examined the impact of HSR on firm birth patterns in different economic sectors. Existing studies have concluded that HSR improves accessibility and stimulates mobility (Cao et al., 2013; Heuermann and Schmieder, 2019). As HSR is designed to move people rather than goods, we expected it to stimulate non-tradeable goods consumption, which has important implications for the growth of the service sector. To explore the heterogeneous effect among different sectors, we ran DID regressions based on the broad economic sectors, primary, manufacturing, and service. The results are reported in Table 5.

Table 5: Regression results by economic sectors

	Total		**Primary**		**Manufacturing**		**Services**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HSR	-0.0617***		-0.177***		-0.153***		0.021	
	(0.0155)		(0.029)		(0.0224)		(0.0162)	
HSR×Urban		-0.0395**		-0.237***		-0.191***		0.0449**
		(0.0199)		(0.0425)		(0.0320)		(0.0218)
HSR×Suburban		-0.075***		-0.142***		-0.13***		0.0067
		(0.0204)		(0.0366)		(0.029)		(0.0217)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province linear trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.84	0.84	0.823	0.823	0.504	0.505	0.803	0.803
Observation	24672	24672	24672	24672	24648	24648	24672	24672

Note: The dependent variable is the natural logarithm of number of new firms. Other controls include the natural logarithms of lag-1 year population, GDP and plant stock. The standard errors are reported in parentheses and clustered at county levels. *, **, and *** refers to the statistical significant at 10%, 5% and 1% respectively.

The results show that the primary and manufacturing sectors declined significantly in both urban and suburban districts with HSR access, as shown in columns (3) to (6) of Table 5. However, we found different patterns for the service sectors, as shown in columns (7) and (8). In urban districts, HSR access increased the number of new firms in the service sector by approximately 4.5%, which was significant at the 5% level. The coefficient in suburban areas was slightly positive, but not significant. Table 6 reports the results for firms in the nine major service sectors. Most sectors showed increasing trends in urban districts, while the effects were mixed in suburban areas. For example, in suburban counties, the number of firms grew in the IT, science and technology, and education sectors, but reduced in the finance sector.

We found that, to some degree, the growing service sector could offset the declining primary and manufacturing sectors in urban districts. In suburban areas, both primary and manufacturing firms declined in number, indicating new additions. HSR appeared to help urban areas move up the value chain by attracting more value-added and knowledge-based firms, which are vital for enhancing agglomeration economies.

Table 6: Regression results by nine service sectors

	IT		Transportation		Leasing & Business Services		Science & Technology		Real Estate		Finance		Whole Sale & Retail		Accommodation & Catering		Education	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
HSR	0.374***		0.0476**		0.0315		0.251***		0.0156		0.05		-0.0271		0.104***		0.294***	
	(0.0323)		(0.0233)		(0.0195)		(0.0262)		(0.0224)		(0.032)		(0.0208)		(0.0244)		(0.0329)	
HSR×Urban		0.629***		0.0579*		0.0256		0.379***		0.0317		0.296***		-0.0519*		0.223***		0.536***
		(0.0437)		(0.0305)		(0.0261)		(0.0335)		(0.0272)		(0.0491)		(0.0295)		(0.034)		(0.0563)
HSR×Suburban		0.223***		0.0414		0.035		0.173***		0.00607		-0.098***		-0.0122		0.0326		0.15***
		(0.0397)		(0.0315)		(0.0261)		(0.0345)		(0.0306)		(0.0378)		(0.0272)		(0.0308)		(0.0384)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Provincial trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.374	0.376	0.598	0.598	0.804	0.804	0.634	0.634	0.498	0.498	0.11	0.112	0.742	0.742	0.534	0.534	0.321	0.324
Observation	24672	24672	24672	24672	24672	24672	24672	24672	24672	24672	24672	24672	24672	24672	24672	24672	24672	24672

Note: The dependent variable is the natural logarithm of number of new firms. Other controls include the natural logarithms of lag-1 year population, GDP and plant stock. The standard errors are reported in parentheses and clustered at county levels. *, **, and *** refers to the statistical significant at 10%, 5% and 1% respective

5.3 Heterogeneities by region

In China, development is unbalanced between the east coast, central, western, and northeast regions. The east coast is the most economically developed region, while the western and northeast regions are considered underdeveloped. Does HSR development have favorable consequences for a particular region, and does it promote balanced regional development? To answer these questions, we examined the impact of HSR on new firm birth by region and economic sectors. The results are reported in Table 7.

Table 7: Regression results by regions and economic sectors

	Total		Primary		Manufacturing		Service	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HSR×Eastern	-0.0671***		-0.284***		-0.125***		0.0409*	
	(0.0222)		(0.0481)		(0.0354)		(0.0235)	
HSR×Central	0.0431*		-0.0625		-0.0506		0.145***	
	(0.0229)		(0.0442)		(0.0358)		(0.0233)	
HSR×Western	-0.223***		-0.253***		-0.340***		-0.132***	
	(0.0355)		(0.0569)		(0.0479)		(0.0393)	
HSR×Northeastern	-0.0758*		0.0246		-0.242***		-0.172***	
	(0.0405)		(0.0804)		(0.048)		(0.04)	
HSR×Eastern×Urban		-0.0458*		-0.308***		-0.164***		0.0579**
		(0.0268)		(0.0776)		(0.0523)		(0.0287)
HSR×Central×Urban		0.0655*		-0.120*		-0.0995*		0.165***
		(0.0334)		(0.0646)		(0.0570)		(0.0383)
HSR×Western×Urban		-0.193***		-0.321***		-0.333***		-0.0821*
		(0.0447)		(0.0773)		(0.0570)		(0.0451)
HSR×Northeastern×Urban		-0.0734		-0.186**		-0.323***		-0.145***
		(0.0464)		(0.0929)		(0.0731)		(0.0447)
HSR×Eastern×Suburban		-0.0801***		-0.271***		-0.102**		0.0308
		(0.0306)		(0.0591)		(0.0467)		(0.0331)
HSR×Central×Suburban		0.0296		-0.0281		-0.0223		0.133***
		(0.0299)		(0.0577)		(0.0445)		(0.0285)
HSR×Western×Suburban		-0.239***		-0.216***		-0.344***		-0.161***
		(0.0483)		(0.0758)		(0.0668)		(0.0550)
HSR×Northeastern×Suburban		-0.078		0.168		-0.185***		-0.190***
		(0.0588)		(0.107)		(0.0591)		(0.0581)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province linear trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.841	0.841	0.824	0.824	0.505	0.506	0.804	0.804
Observation	24672	24672	24672	24672	24648	24648	24672	24672

Note: The dependent variable is the natural logarithm of number of new firms. Other controls include the natural logarithms of lag-1 year population, GDP and plant stock. The standard errors are reported in parentheses and clustered at county levels. *, **, and *** refers to the statistical significant at 10%, 5% and 1% respectively.

We found that the primary and manufacturing sectors showed a declining trend after HSR access, and this trend appeared in both urban and suburban districts in nearly all regions, as shown in columns (3) to (6) of Table 7. For the service sector, the east coast and central region coefficients were positive in both urban and suburban districts. The number of new firms in the central region grew by approximately 16.5% in urban districts and 13.3% in suburban districts, and both results were significant. For the western and northeast regions, the service sector contracted in both urban and suburban districts. The heterogenous effects across sectors and regions help to rationalize the overall negative effect of HSR on the birth of new firms because the decline in primary and manufacturing sectors is overwhelming, and the growth of service firms cannot offset the decline in other sectors. However, HSR helps cities to upgrade the value chain by attracting more value-added firms to come up in cities.

6. Understanding the heterogeneities

How can the spatial heterogeneity of new firm births be explained? One way to understand these patterns is to explore the impact of HSR on demographic and economic changes. We examined the impact of HSR on population and land prices through a similar DID regression by employing equation (1). The results are listed in Table 8. The dependent variables were the natural logarithms of the population and the residential and service land prices.

Table 8: The impact of HSR to population and land prices

	Population		Residential Land		Service Land	
	(1)	(2)	(3)	(4)	(5)	(6)
HSR	0.022***		0.0502*		0.0788**	
	(0.00832)		(0.0271)		(0.0325)	
HSR×Urban		0.108***		0.109***		0.111**
		(0.0178)		(0.0389)		(0.0479)
HSR×Suburban		-0.0308***		0.0109		0.0565
		(0.00594)		(0.0356)		(0.041)
County effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Province linear trend	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.119	0.14	0.41	0.41	0.212	0.212
Observation	26897	26897	18883	18883	17557	17557

Note: The dependent variable is the natural logarithm of population and GDP. The standard errors are reported in parentheses and clustered at county levels. *, **, and *** refers to the statistical significant at 10%, 5% and 1% respectively.

The first column of Table 8 demonstrates that the population increased by approximately 2.2% in districts with HSR access. However, this effect was quite different for urban and suburban districts, as shown in column (2). The population in urban districts increased by approximately 11%, while it decreased by approximately 3.1% in suburban counties. All results were statistically significant at the 1% level. These results at the county level are consistent with the literature that HSR favors the growth of larger cities at the expense of nearby small cities (Qin, 2017). Columns (3) to (6) summarize changes in the residential and service land prices. We found that the land price for both types of land use increased by approximately 11% in urban districts; the results are very robust. The coefficients in suburban areas were also positive, although not significant.

The population and land price patterns shed light on the disparity in new firm births between the manufacturing and service sectors. After HSR started, more people moved to urban areas in pursuit of emerging opportunities and amenities. Therefore, we expected a growing service sector in urban districts, given the integrated market, and the land price increase owing to the rising demand. In the spatial equilibrium framework (Roback, 1982), urban employment wages are expected to go up to offset the higher rents if the improvement in urban amenities (HSR accessibility benefits) is not strong enough for cities. We do not have wage data at the county level, but the literature suggests a wage premium due to the reinforced urban agglomeration (Glaeser and Mare, 2001; Gould, 2007). The rising land price and possible labor cost in urban districts caused by HSR development can explain out-migration of primary and manufacturing sectors.

7. Conclusion

This study explored the causal effects of HSR access on the spatial patterns of new firm births in China through a set of DID regressions. We demonstrated that a new firm's location choice is affected by both agglomeration economics and HSR access. New firms are more likely to locate near peers from the same industry, and the agglomeration effect is significant for all types of firms in all regions. An HSR network can significantly enhance the market access and integration of affected regions, influencing the location choice of firms. However, the effect of HSR access on new firm births showed substantial heterogeneity. The pattern varied with the location of HSR stations between urban and suburban districts and was also influenced by industrial type and geographical region. Table 9 summarizes the heterogeneities and reports the significance levels of the coefficients on HSR access.

Table 9: Summary of empirical findings

	All firms			**Manufacturing**			**Service**		
	All	Urban	Suburban	All	Urban	Suburban	All	Urban	Suburban
Overall	---	--	---	---	---	---		++	
Eastern	---	-	---	---	---	--	+	++	
Central	+	+			-		+++	+++	+++
Western	---	---	---	---	---	---	---	-	---
Northeastern	-			---	---	---	---	---	---

Note: "+" indicates the coefficient of HSR on new firm birth is positive, and "-"indicates the number of new firms declines after HSR. . +, ++, and +++ refers to the positive coefficient with statistical significant levels at 10%, 5% and 1% respectively. Similarly, -, --, and --- refer to the negative coefficient with statistical significant levels at 10%, 5% and 1% respectively

To understand these patterns, we examined the impact of HSR on population and land prices in affected counties. We found that the population increased in urban areas and declined in suburban counties. We also found a robust pattern of land price appreciation, for both residential and service land use, in urban districts. We argue that while population growth and market integration in urban districts can explain the overall clustering pattern of the service sector, the rising costs due to HSR access could be the reason why primary and manufacturing firms ultimately leave these districts.

This study contributes to the literature on agglomeration economics, firm location choice, link between transportation and economic development, and regional development. The findings of this study are consistent with those of the literature. For example, the clustering of the services industries in urban districts and the out-migration of the primary and manufacturing firms are consistent with both urban economic theory and empirical evidence (Chang, 2021; Murakami and Cervero, 2017). Additionally, we verify the redistribution effect of HSR, which favors larger cities and is detrimental to small and underdeveloped cities (Qin, 2017; Zheng et al., 2019). Our results show that understanding firm establishment patterns is critical to understanding industrial clusters and economic growth.

Our results yield a number of implications for both public and private sectors. First, local governments regarded HSR as a development anchor to boost economic growth and competed for HSR access intensively (Chang, 2021). However, our results show that securing a HSR station could probably hurt local development as the number of new firms in all sectors could decline significantly, especially for less developed regions. Planners may bear the consequences of spatial inequality in mind when they plan a new HSR routes. Local governments should also consider carefully whether HSR can bring benefits for their jurisdiction or not. Second, for the east coast and central regions, we found HSR can enhance service sector agglomerations and manufacturing decentralization, especially in urban districts. This suggests HSR can be a substitute for industry policy by upgrading the value chain and attracting more value-added firms to urban areas. The growing service sector in large cities can help more cities to transform from production city to consumer cities (Glaeser et al., 2001). Lastly, our results have implication for private sectors and labor markets as well. As HSR networks can change the pattern of firm establishment for each location, investors in different sectors must carefully consider their establishment decisions to maximize their profits. Residents may realize this pattern to explore labor market opportunities in different sectors.

We highlight several analytical challenges for future research. First, we found a redistribution effect of HSR between urban and suburban areas and across regions. HSR resulted in benefits for certain districts, while other districts were left behind. Whether HSR can bring a net benefit to a country needs to be studied. Second, our study focused on firms' extensive margin rather than intensive margin. The changing spatial pattern of new firm births is likely to be associated with firm performance. Whether clustering of the services sector and relocation of the primary and manufacturing sectors can enhance productivity is an important topic worth pursuing. Third, this study demonstrated the different impacts across China's four regions. We found that central China is the most attractive to new firms. As underdeveloped regions are less attractive due to HSR access, particularly for services firms, it is not clear why the central region stands out due to HSR access. We hope future research addresses these analytical challenges.

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