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Fengyi Zheng: Writing – original draft, Visualization, Software, Methodology, Formal analysis, Funding acquisition.

Cong Hu: Writing – original draft, review & editing, Data curation, Conceptualization.

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None.

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Data availability

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ABSTRACT: The economic impacts of high-speed railway (HSR) connection on regional development remain contested in the literature. From the perspective of county economic status, this study investigates the county-level effects of HSR connection in China and addresses the salient practical challenge of the persistent marginalization of county economy and the weak endogenous development momentum. Using county-level panel data spanning 1999 to 2023, we find that HSR connection has significantly reduced county economic status. Heterogeneity analysis yields three key findings. First, temporally, the negative effect only materialized after 2008, when China initiated large-scale, standardized and networked HSR development. Second, geographically, the negative effect is present only in the eastern and northeastern regions, especially with a stronger negative shock in the northeast, whereas no such effect is observed in the central and western regions. Third, regarding county characteristics, the effect is more pronounced in counties with larger population sizes but absent in those with extremely small ones; it is also typically confined to counties with low industrialization levels, and non-natural-resource-based as well as non-tourism-oriented counties. Mechanism tests demonstrate that HSR connection erodes counties' endogenous development momentum and perpetuates their economic marginalization mainly through the outflows of labor and capital, as well as the loss of land factors driven by cropland abandonment. Further moderating effect analysis reveals that the location of HSR stations moderates these negative effects. A shorter distance between the HSR station

and the county center reinforces the labor and capital outflow channels, thus amplifying the negative effect. However, this moderating effect does not extend to the land factor loss mechanism associated with cropland abandonment.

Keywords: High-speed railway; County economic status; Factor outflow; HSR station location; China’s counties

1. Introduction

Counties constitute the fundamental units of China's national economy. Accounting for over 90% of the national land area, they sustain the production activities, daily livelihoods, and employment of more than 50% of the country's population, thereby serving as the backbone for stabilizing the fundamentals of people's livelihoods and supporting the stable operation of the overall national economy. However, according to the *China County Statistical Yearbook (2024)*, in more than 60% of China's provincial-level regions, county-level GDP accounts for less than 30% of the provincial economic aggregate, and in some provinces this share even falls below 20%. This implies that the vast county territories and their populations generate merely one-fifth of provincial economic output, revealing a severe mismatch between the volume of foundational resources held by counties and their economic contribution. Such disparities highlight the persistent marginalization of county economic status, alongside the practical problem of weak endogenous development momentum.

Through the lens of new economic geography, transportation costs are a core determinant of the spatial distribution of economic activity (Krugman, 1991), and they may exert asymmetric effects on jurisdictions at varying administrative levels. Unlike conventional transport infrastructure, high-speed railway (HSR) represents a revolutionary breakthrough in transportation technology. Its core advantage lies in drastically driving time-space compression and reducing transportation costs, thereby restructuring the spatiotemporal organization of economic activity and amplifying such asymmetry. Since the opening of China's first HSR line—the Qinhuangdao–Shenyang Passenger Dedicated Line—in 2003, China's HSR network has expanded rapidly. By the end of 2025, the HSR operating mileage had surpassed 50,000 km, the largest in the world, covering 97% of Chinese cities with a population exceeding 500,000. This raises a critical question: are the persistent marginalization of county economic status and the weak endogenous development momentum, as currently observed in China, a manifestation of such asymmetric effects at the provincial scale amid the rapid expansion of the HSR network?

However, the empirical evidence on the impact of HSR connection on regional economies remains mixed. On the one hand, the railway, a classic form of transport

infrastructure, reduces interregional trade costs and improves resource allocation efficiency (Donaldson, 2018). As a modern passenger-oriented railway innovation, HSR further facilitates the free flow of production factors such as labor. Additionally, HSR has been shown to promote industrial structure upgrading (Li et al., 2025), narrow inter-county economic disparities (Chen et al., 2023), and stimulate economic growth (Ke et al., 2017; Yao et al., 2020; Wang and Dong, 2022), with the growth effect intensifying over the operation period (Wang and Dong, 2022). On the other hand, HSR has also exacerbated uneven regional development. It can lead to the contraction of industrial output and the persistent outflow of high-skilled labor in peripheral regions (Yu et al., 2019), further exacerbating their economic slowdown (Gao et al., 2020). With respect to industrial location, HSR drives the agglomeration of producer services in central cities while promoting the dispersion of consumer services toward peripheral counties (Chang et al., 2025), further widening the development gap between central cities and peripheral ones.

Existing research has well documented the dual effects of HSR connection on regional economies, yet considerable room for extension remains. First, most studies focus on absolute indicators such as GDP, neglecting shifts in relative economic status—particularly for peripheral units such as counties. Compared with absolute growth, shifts in relative economic status offer greater theoretical and practical insight into balanced and sustainable regional development. Second, studies have concentrated more on localized economic belts such as an individual HSR line or the Yangtze River Basin, which cannot capture the county-level picture nationwide. Given China's vast territory and stark regional disparities in resource endowments, only a nationwide county-level analysis can avoid the selection bias of localized samples and identify the generalizable effects of HSR connection. Third, few studies have adopted the perspective of endogenous development momentum to explain how HSR connection affects relative economic status. Only by tracing factor flows and their allocation efficiency can we determine whether HSR shapes county economic status through "agglomeration" or "siphoning". Fourth, although scholars have recognized that HSR effects vary with operating time, the moderating effect of station location has rarely been examined. Compared with a binary indicator of HSR presence, the precise distance between HSR stations and county centers more accurately captures the true costs of HSR connection and reduces measurement bias.

This study makes three contributions. First, it shifts the focus from absolute growth to changes in relative economic status. Using a county-level database of HSR openings in China built from web-scraped and manually compiled data, we examine how HSR connection reshapes the economic standing of counties within their provincial economies, thereby identifying the key drivers of the persistent marginalization of county economic status and providing fine-grained county-level evidence on the new

economic geography. Second, it traces the impact of HSR connection on county economic status to three endogenous development factors—labor, capital, and land. We show that labor and capital outflows, together with land loss from cropland abandonment, erode counties' endogenous development momentum, deepening the mechanistic understanding of how transport improvements shape regional development. Third, exploiting the spatial richness of this unique database, we investigate how the distance between HSR stations and county centers moderates both the effects of HSR connection on county economic status and the mechanisms behind them.

This study is structured as follows. Section 2 shows the theoretical mechanism and hypotheses. Section 3 lays out the data and the empirical strategy. Section 4 presents the main results. Section 5 discusses possible mechanisms. Section 6 concludes.

2. Theoretical analysis

2.1. The impact of HSR connection on county economic status

Although a large body of research has documented the positive effects of HSR connection on regional economies (Yao et al., 2020; Wang and Dong, 2022), HSR connection may also accelerate the net flow of production factors from peripheral to core regions, thereby imposing negative shocks on their economic development (Zhang and Gibson, 2025). As typical peripheral units within China, counties often occupy a passive and disadvantaged position in the process of HSR-induced factor reallocation.

For labor, HSR compresses spatiotemporal distances and lowers the time and costs of mobility, thereby breaking down spatial barriers to cross-regional labor flows. Workers are thus able to move across provincial administrative and city-cluster boundaries (Jiao et al., 2025), search over larger geographic areas for jobs better matched to their skills (De Borger et al., 2025), and increasingly agglomerate in higher-tier cities (Wang et al., 2022). In this process of factor reallocation, less developed regions and small and medium-sized cities become the primary sources of labor outflows; persistent interregional labor mobility continuously depletes local labor pool, and the human capital base underpinning economic growth weakens accordingly (Jiao et al., 2025; Wang et al., 2022). Consequently, improved external transport connectivity accelerates the loss of labor from counties, and the resulting chronic shortage of talent directly constrains the cultivation, transformation, and upgrading of local industries, ultimately causing their economic standing to decline continuously.

For capital, the absence of industrial clusters—an organizational form that enhances regional productivity and cross-firm resource allocation efficiency (Guo et al., 2023)—leaves most counties with lower factor utilization efficiency, putting them at a structural disadvantage in capital markets due to limited investment returns. Driven by

the profit-seeking nature of capital, central cities—with more complete industrial supporting facilities, higher returns on capital, and superior financial service systems—exert a strong pull on county capital, a backwash pattern long documented across China's urban hierarchy (Chen and Partridge, 2013). By reducing spatial frictions to interregional capital flows, HSR connection significantly increases the mobility of capital across cities (Duan et al., 2021): improved information transmission and brighter growth prospects then drive capital to spontaneously agglomerate in core cities, widening the gap in capital allocation between core cities and counties. Meanwhile, HSR reduces commuting and transaction costs for county residents to access high-end financial services in large cities, diverting local deposits and loans toward core cities and dampening county-level fixed-asset investment (Dong et al., 2023). Consequently, by reshaping the spatial allocation of regional capital and inducing persistent capital outflows, HSR continuously squeezes the funding supply for county industrial development, weakens the capital foundation of county economies, and causes their economic standing to decline continuously.

For land, HSR connection, while accelerating the outflows of labor and capital, also induces cropland abandonment and the resulting loss of land factors, thereby weakening county economic status. On the one hand, HSR connection improves regional transport accessibility, facilitates agricultural labor outflow to non-farm sectors, and reduces cropland availability, with this effect being particularly pronounced in less developed counties (Chen et al., 2026). Moreover, HSR connection has significantly reduced the permanent population of connected counties amid the agglomeration shadow effect (Zhang and Chen, 2022), and such sustained population loss may further exacerbate the decline in cropland use and intensify abandonment in the agricultural sector. On the other hand, the land factor is precisely where counties are most exposed: county economies in the main grain-producing areas remain heavily tied to farmland and grain production (Yang et al., 2024), rendering them particularly sensitive to the loss of land factors. Large-scale cropland abandonment directly translates into substantial grain production losses (Li et al., 2026), erodes the foundation of county agricultural development, and ultimately causes the standing of counties in the regional economic system to decline continuously.

Therefore, we propose the following hypotheses.

Hypothesis 1. HSR connection reduces county economic status.

Hypothesis 2. HSR connection reduces county economic status through three mechanisms: the outflow of labor and capital, and the loss of land factors driven by

cropland abandonment.

2.2. The role of HSR station location

The economic effects of HSR vary significantly with the station's distance from the city center (Diao et al., 2017; Liu et al., 2024). In terms of factor mobility, labor and capital are characterized by cross-regional mobility, and the extent of their outflow is highly sensitive to station location. Cropland, by contrast, is a spatially fixed and immobile production factor; abandonment decisions depend on changes in the relative returns to farming versus non-farm employment, and may thus be less constrained by differences in station location.

The core role of HSR connection in cross-regional labor allocation lies in compressing the time costs of intercity travel and facilitating cross-city labor sourcing (Lin, 2017); in counties along the route, this has translated into a significant reduction in permanent population (Zhang and Chen, 2022). The reach and intensity of this role, however, are bounded by station location. The localized spillover effects of HSR stations decline as their distance from the city center increases (Zheng et al., 2019); conversely, when a station sits close to the county center, the main population concentrations fall within the hub's catchment, substantially lowering the mobility thresholds for intercity commuting and non-local employment.

The county center is also the core agglomeration site for local industry and commerce, financial resources, and investment activities. When an HSR station is located close to the urban core, executives of local commercial banks, corporate investment decision-makers, and private capital owners can connect with financial institutions, industrial parks, and capital markets in provincial central cities through only a very short commute, substantially reducing the transaction costs of business exchanges, information sharing, and capital matchmaking between local agents and external central cities, and further breaking the spatial constraints on cross-regional capital flows from counties. Compared with counties served by remote stations, those with a station close to the urban core experience more pronounced outflows of idle capital and financial credit resources toward central cities. Consistent with this mechanism, county-level evidence shows that HSR connection drives bank affiliates, deposits, and loans to cluster toward larger counties, while smaller counties face shrinking local funding, contracting fixed-asset investment, and declining output (Dong et al., 2023) — a dynamic that amplifies the negative effect of HSR connection on peripheral counties' economic standing.

Labor and capital are factors that can flow across regions, and the intensity of their flows is subject to the travel costs and transaction costs determined by station location; cropland differs markedly in this respect. As a spatially immobile production factor, whether cropland is abandoned hinges fundamentally on the opportunity cost of farm labor — rising off-farm employment significantly raises the likelihood of abandonment

(Zhang et al., 2026) — rather than on improvements in transport accessibility per se. HSR connection expands non-agricultural employment across connected counties (Lu and Li, 2025). While the magnitude of these employment gains varies with station location, their county-wide reach systematically raises the overall opportunity cost of agricultural production, strengthens rural laborers' willingness to transfer to non-farm sectors, and drives a general decline in the agricultural labor stock — even for counties with remotely sited stations. Against this backdrop, adjustments in cropland use behavior are endogenous to changes in household labor endowments (Yan et al., 2016; He et al., 2020).

When the remaining agricultural population is insufficient to sustain existing cultivation intensity, abandonment becomes a rational choice for farm households under labor constraints. The key to this decision lies in labor loss itself, rather than in the spatial distance between households and HSR stations. Therefore, although station location can alter the efficiency of factor flows between counties and central cities, it has limited influence on cropland abandonment—a structural change process rooted in agricultural labor supply. The transmission mechanism through which HSR connection induces cropland abandonment and the loss of land factors is not constrained by the spatial distance between HSR stations and county centers.

Therefore, we propose the following hypotheses.

Hypothesis 3. The negative effect of HSR connection on county economic status is moderated by the location of HSR stations: the closer the station to the county center, the stronger the negative effect.

Hypothesis 4. Station location affects the negative effect of HSR connection on county economic status through the outflow of labor and capital, but does not operate through the loss of land factors associated with cropland abandonment. Specifically, a shorter distance between the HSR station and the county center amplifies the outflow of labor and capital, thereby intensifying the negative effect of HSR connection.

3. Data and methodology

3.1. Data sources

This study draws on three main types of data sources. The first is county-level HSR opening data, compiled through web scraping and manual collation from the *China Railway Yearbook*, the *China Transport Yearbook*, official announcements of China State Railway Group, and authoritative media reports. The second is HSR station location data, likewise obtained through a combination of web scraping and manual verification: the road distance from each county's nearest HSR station to the county center was extracted via Amap, with the seat of the county people's government taken as the benchmark for the county center. The third is county-level economic statistics, whose primary sources are the *China Statistical Yearbook*, the *China Regional*

Economic Statistical Yearbook, and the *China County Statistical Yearbook*, supplemented by provincial statistical yearbooks and local statistical communiqués on national economic and social development to fill in missing indicators, thereby constructing the core variables measuring county economic status and various control variables.

The sample comprises 1,807 county-level units across China over the period 1999–2023, yielding 44,622 county-year observations. These units consist of 1,359 counties, 394 county-level cities, 52 banners, one forestry district, and one special district. Beijing, Shanghai, Tianjin, and Tibet are excluded from the sample: the first three contain no counties or county-level cities within their administrative divisions, and Tibet recorded no HSR during the study period. All variables are either transformed using the inverse hyperbolic sine (IHS) function or log-transformed. Descriptive statistics of all variables are reported in Table 1.

3.2. Measures

3.2.1. Dependent variables

The measurement of county economic status draws on the research designs of Ades and Glaeser (1995), who measure urban primacy using population share, and Ioannou and Wójcik (2021), who do so using GDP share. Accordingly, we adopt the share of each county's GDP in its province as the indicator: an increase in this share represents a rise in the county's relative economic status, while a decrease represents a decline.

3.2.2. Independent variables

HSR connection in a county is captured by a dummy variable. In this study, HSR refers to railway lines with an actual operating speed of 200 km/h[1]. Regarding the timing of HSR connection, we follow the approach of Gu and Wan (2020): for counties where HSR opened in the first half of a year, the dummy variable takes the value of 1 from that year onward; for counties where HSR opened in the second half of a year, it takes the value of 1 from the following year onward.

3.2.3. Mechanism variables

To identify the mechanisms through which HSR connection affects county economic status, this study constructs mechanism variables along three factor

[1] Article 5 of China's *Main Technical Policies of Railways* (Order No. 34 of the Ministry of Railways) stipulates that high-speed railway refers to newly built passenger dedicated lines designed for electric multiple unit (EMU) trains operating at 250 km/h or above (including reserved capacity), with an initial operating speed of no less than 200 km/h. However, some railway lines currently in operation have a design speed below 250 km/h but an actual operating speed reaching 200 km/h. Given that the HSR effect depends primarily on the actual operating speed, this study treats such lines as HSR.

dimensions. First, for the labor outflow mechanism, the ratio of persons employed in units (a Chinese statistical category approximating formal-sector employment) at year-end to the year-end total population is adopted as the proxy variable; a decline in this ratio indicates labor outflow from the county. Second, for the capital outflow mechanism, the balance of household deposits is adopted as the proxy variable; a decrease in this indicator indicates an outflow of household funds. Third, for the land factor loss mechanism through cropland abandonment, the total sown area of crops is adopted as the proxy variable; a decrease in this indicator implies that part of the cropland has been withdrawn from agricultural cultivation, capturing land factors leaving agricultural production and lying abandoned or idle.

3.2.4. Moderating variable

The moderating variable is HSR station location. The raw indicator is the road distance from each county's nearest HSR station to the seat of the county people's government: the larger the distance, the more remote the station, and the smaller the distance, the closer the station is to the county center. To unify the interpretation of coefficients, we apply a reciprocal transformation to the raw distance, such that a larger transformed value indicates that the HSR station is closer to the county center, while a smaller value indicates a more remote station.

3.2.5. Control variables

This study selects a series of regional characteristic indicators that may affect the relative economic status of counties as control variables. County area is measured by the land area of the administrative region, population size by the year-end total population, servicification by the ratio of value added of the tertiary industry to GDP, residents' income level by the per capita disposable income of rural residents, and local employment size by persons employed in units at year-end. In the robustness tests, three additional indicators—investment scale, industrialization level, and fiscal self-sufficiency—are added to the set of baseline control variables. Specifically, investment scale is measured by total fixed-asset investment, industrialization level by the ratio of value added of the secondary industry to that of the tertiary industry, and fiscal self-sufficiency by the ratio of local general public budget revenue to expenditure. Definitions and descriptive statistics of all variables are reported in Table 1.

3.3. Empirical strategy

HSR connection is highly exogenous and thus provides a quasi-experimental setting. On the one hand, HSR route planning in China is centrally coordinated at the national level and is only weakly constrained by county-level factors such as local economic development and fiscal capacity. On the other hand, the timing of HSR opening at each station is clearly defined with complete publicly available information, and the rollout of HSR across counties exhibits a staggered, phased pattern. These features indicate that the HSR opening shock satisfies the requirements of the difference-in-differences (DID) model regarding shock exogeneity and well-defined

treatment timing. Therefore, this study employs a DID model to identify the impact of HSR connection on county economic status, with the baseline model specified as follows:

$$GDP\ share_{i,t} = \alpha_0 + \alpha_1(Hsr_i * Post_t) + \alpha_2 X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

where $GDP\ share_{i,t}$ is the dependent variable, namely the county economic status of county i in year t, measured by the share of the county's GDP in its province; α_0 is the constant term; α_1 is the core coefficient; $Hsr_i * Post_t$ is the core independent variable, HSR connection. Hsr_i is the treatment group dummy, which equals 1 if county i has opened HSR and 0 otherwise; $Post_t$ is the policy timing dummy, which equals 1 for the years after county i opens HSR, and 0 for the years before opening as well as for counties that never open HSR. $X_{i,t}$ denotes the set of control variables, μ_i denotes county fixed effects, λ_t denotes time fixed effects, and $\varepsilon_{i,t}$ is the random error term.

To examine the role of HSR station location in the process by which HSR connection reduces county economic status, this study adopts the interaction term approach—that is, adding the HSR station location variable and its interaction with HSR connection to the baseline model in Equation (1). The model is specified as follows:

$$Y(GDP\ share)_{i,t} = \delta_0 + \delta_1(Hsr_i * Post_t) + \delta_2\left(Hsr_i * Post_t * Sta_{i,t}\right) + \delta_3\left(Sta_{i,t}\right) + \delta_4 X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (2)$$

where $Sta_{i,t}$ is HSR station location, and δ_2 is the estimated coefficient of the interaction term between the HSR connection variable and the HSR station location variable. To further investigate the mechanisms through which HSR connection affects county economic status, as well as the moderating effect of station location, this study specifies the following model for testing at two levels:

$$Med_{i,t} = \beta_0 + \beta_1(Hsr_i * Post_t) + \beta_2 X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (3)$$

$$Med_{i,t} = \gamma_0 + \gamma_1(Hsr_i * Post_t) + \gamma_2\left(Hsr_i * Post_t * Sta_{i,t}\right) + \gamma_3\left(Sta_{i,t}\right) + \gamma_4 X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (4)$$

Equation (3) performs the first level of testing, namely, examining whether the mechanisms through which HSR connection affects county economic status exist. $Med_{i,t}$ denotes the set of mechanism variables, including the labor outflow mechanism, the capital outflow mechanism, and the land factor loss mechanism through cropland abandonment. Equation (3) focuses on β_1: if β_1 is statistically significant, the mechanisms of HSR connection are validated. Equation (4) performs the second level of testing, namely, examining whether HSR station location strengthens these mechanisms. Equation (4) focuses on γ_2: if γ_2 is statistically significant, it indicates that station location influences the mechanisms of HSR connection.

Table 1

Variable definition and descriptive statistics.

Variable definition	Obs.	Mean	S.D.	Min.	Max.
$GDP\ share$: county economic status (%), share of a county's GDP in its province	45148	0.728	0.853	0.311	18.74
$Hsr * Post$: HSR connection	45172	0.0813	0.273	0	1
Are : County area, Land area of the administrative region (km^2)	45147	4154	9545	56	22274
Pop: Population size, Year-end total population (10,000 persons)	45172	45.80	33.11	0.170	243
Ser: Servicification, Ratio of value added of the tertiary industry to GDP	45172	0.364	0.115	0.00128	0.985
Inc : Residents' income level, Per capita disposable income of rural residents (yuan)	44672	8755	8411	19.79	188124
Emp: Employment size, Persons employed in units at year-end (10,000 persons)	44647	2.714	3.418	0.0703	83.74
Inv : Investment scale, Total fixed-asset investment (100 million yuan)	44874	60.77	92.38	0.0704	1393
Ind : Industrialization level, Ratio of value added of the secondary industry to that of the tertiary industry	45049	1.756	45.58	0	7652
Fis : Fiscal self-sufficiency, Ratio of local general public budget revenue to expenditure (%)	45123	34.62	57.11	0.0022	3326
Sta: Station location, Reciprocal of the road distance from the county's nearest HSR station to the county people's government (in 100 meters)	45172	0.0017	0.0015	0.0001	0.0167

4. Results

4.1. Baseline result

The baseline model estimates the average treatment effect of HSR connection on county economic status across all counties, and the results are reported in Table 2. Column (1) of Table 2 presents the regression results without control variables, controlling only for county and year fixed effects: the estimated coefficient of the independent variable is −0.0645, which is significantly negative at the 1% level, indicating that HSR connection reduces county economic status—that is, it lowers the share of the county's GDP in its province. Furthermore, in Columns (2)–(6) of Table 2, the estimated coefficient of the independent variable remains significantly negative as control variables are progressively added. The baseline regression results thus support Hypothesis 1. Column (7) of Table 2 reports the effect arising from HSR station location. The results show that the coefficient of the interaction term between HSR connection and station location is significantly negative, indicating that a shorter distance between the station and the county center amplifies the negative effect of HSR connection on

county economic status. Hypothesis 3 is thus supported.

Table 2

Baseline regression results

Variable	Dependent variable: county economic status						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Hsr * Post$	-0.0645***	-0.0641***	-0.0693***	-0.0663***	-0.0535***	-0.0547***	-0.0560**
	(-3.2441)	(-3.2201)	(-3.5320)	(-3.3906)	(-2.7646)	(-2.8341)	(-2.4425)
Are		0.0784	0.0649	0.0609	0.0421	0.0412	0.0417
		(1.5173)	(1.2606)	(1.2662)	(0.9172)	(0.8922)	(0.9035)
Pop			0.0389	0.0462	0.0428	0.0397	0.0397
			(1.3874)	(1.6045)	(1.4265)	(1.4342)	(1.4362)
Ser				-0.7712***	-0.6684***	-0.6752***	-0.6749***
				(-7.6515)	(-7.9035)	(-7.9885)	(-7.9860)
Inc					0.1602***	0.1596***	0.1597***
					(5.9668)	(5.9785)	(5.9825)
Emp						0.0293***	0.0292***
						(3.5634)	(3.5630)
$Hsr * Post * Sta$							-4.3969**
							(-2.1237)
Sta							4.4063**
							(2.1350)
Constant	0.7374***	0.1306	-0.2644	-0.0956	-1.1440**	-1.3831***	-1.3865***
	(69.8890)	(0.3275)	(-0.5518)	(-0.2037)	(-2.1926)	(-2.6958)	(-2.7050)
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	45148	45123	44797	44797	44647	44622	44622
Adjusted R^2	0.0576	0.0197	0.0336	0.0558	0.1512	0.1854	0.1505

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Z-statistics are in parentheses.

4.2. Robustness checks

4.2.1. Common trends test

The DID approach requires that the treatment and control groups exhibit consistent trends before the policy takes effect. This study selects the six years before and the four years after HSR opening for the test. As the timing of HSR opening varies across counties, we bin the endpoints of the event window in processing the data. To avoid multicollinearity, the period immediately before policy implementation is taken as the reference group. The common trends test results in Fig. 1 show that the estimated coefficients for the pre-opening periods do not change significantly, indicating no

significant differences in county economic status between the treatment and control groups prior to HSR opening. After HSR opening, however, the county economic status of the treatment group declines significantly, with the absolute magnitude of the coefficients increasing year by year. This indicates that HSR connection is the key factor driving the changes in county economic status between the two groups, and the common trends test is thus passed.

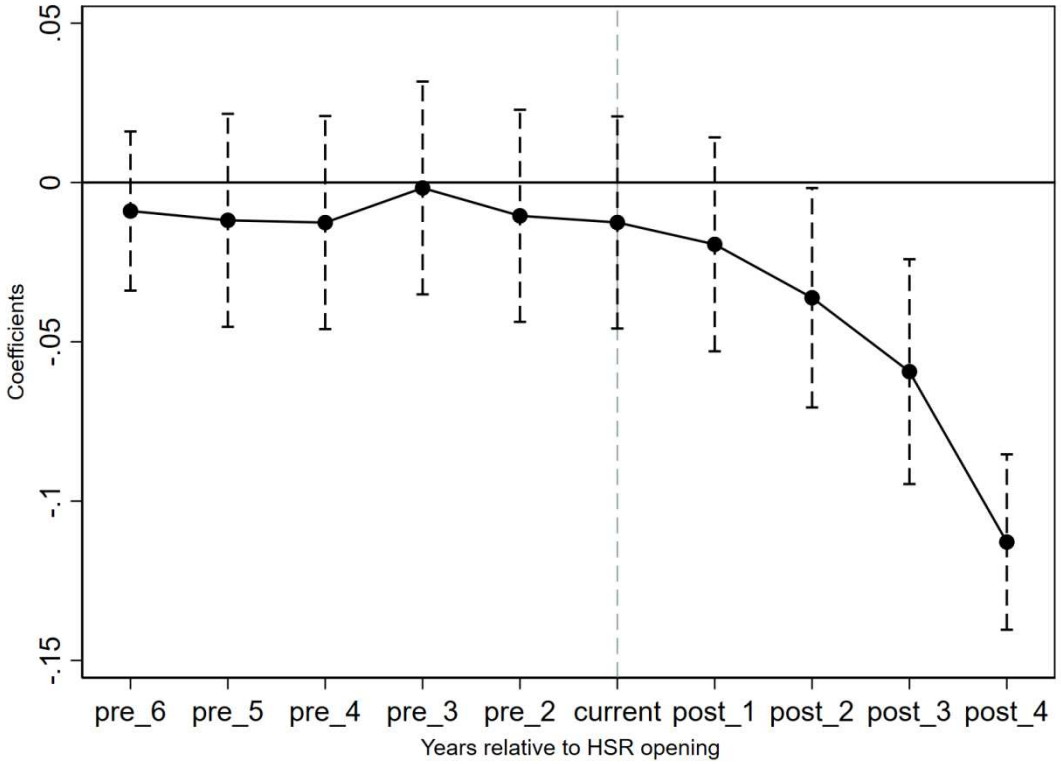


Fig. 1. Event study plot for common trends test.

4.2.2 Adding control variables

To further mitigate the potential impact of omitted variable bias on the estimation results, this study introduces investment scale, industrialization level, and fiscal self-sufficiency as additional control variables beyond the original set, and conducts robustness tests. Columns (1)–(3) of Table 3 report the regression results with these additional control variables progressively added. The results show that the estimated coefficient of HSR connection on county economic status remains significantly negative. This indicates that, after controlling for potential confounding factors such as investment scale, industrialization, and fiscal self-sufficiency, the negative effect of HSR connection on county economic status remains robust, supporting the reliability of the baseline regression results.

Table 3

Robustness test regression results

Variable	Dependent variable: county economic status		
	(1)	(2)	(3)
$Hsr * Post$	-0.0541***	-0.0514***	-0.0468**
	(-2.7954)	(-2.6763)	(-2.5165)
Are	0.0427	0.0527	0.0547
	(0.9007)	(1.0786)	(1.0624)
Pop	0.0425	0.0350	0.0210
	(1.4944)	(1.4150)	(0.9899)
Ser	-0.6417***	-0.3666**	-0.3276*
	(-7.8315)	(-2.0005)	(-1.9064)
Inc	0.1462***	0.1407***	0.1185***
	(5.8642)	(5.5573)	(4.8163)
Emp	0.0296***	0.0287***	0.0242***
	(3.5898)	(3.5242)	(3.3228)
Inv	0.0356***	0.0329***	0.0255***
	(5.2706)	(4.8304)	(3.8878)
Ind		0.0430*	0.0396
		(1.6587)	(1.6338)
Fis			0.5015***
			(10.2058)
Constant	-1.6944***	-1.7386***	-1.5708***
	(-3.2296)	(-3.3025)	(-3.0214)
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	44622	44548	44548
Adjusted R^2	0.2127	0.2344	0.2581

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Z-statistics are in parentheses.

4.2.3 Replacing the measure of the dependent variable

Since the baseline regression measures county economic status by the share of each county's GDP in its province, this section replaces the measure of the dependent variable with the share of each county's per capita GDP in its province, and conducts robustness tests accordingly. This adjustment is well justified. First, per capita GDP removes the influence of population size and thus better reflects the quality and efficiency of county economic development, avoiding the distortion whereby the inflated aggregate output of populous counties masks their actual development levels. Second, comparing counties within a province on a per capita basis more fairly reflects the average economic welfare and productivity of residents across counties. The regression results are reported in Column (1) of Table 4, which show that the estimated coefficient of the core independent variable, HSR connection, on county economic status remains significantly negative. This indicates that, after replacing the measure of

the dependent variable, HSR connection still exerts a significant negative effect on county economic status, consistent with the findings of the baseline regression.

4.2.4 Incorporating multidimensional interactive fixed effects

As the timing of HSR opening varies across regions and county economies follow distinct development trajectories, this section includes county-specific year trends to control for the influence of such trends. On the basis of the baseline model, we further add county–year interactive fixed effects—namely, the interaction between county fixed effects and year fixed effects—to control for unobserved time-varying effects at the regional level. The estimation results are reported in Column (2) of Table 4, where the coefficient of the core independent variable, HSR connection, is significantly negative. This indicates that the negative effect of HSR connection on county economic status remains robust after incorporating multidimensional interactive fixed effects.

4.2.5 Excluding observations from the special period

The year 2020 was an exceptional year in which the COVID-19 pandemic struck most severely worldwide, causing extensive and far-reaching disruptions to economic and social operations. The pandemic's impact was particularly pronounced on the two core variables of this study. On the one hand, the progress of HSR construction and opening slowed due to pandemic containment measures, mobility restrictions, and construction suspensions, and some lines originally scheduled to open in 2020 were delayed, causing the timing of the policy shock of HSR opening to shift or become distorted. On the other hand, county economic activities were generally hit amid the pandemic—with shrinking consumption, disrupted employment, and declining fiscal revenue—such that key economic indicators deviated substantially from normal growth trajectories and could hardly reflect the long-term structural impact of HSR connection. Including the 2020 sample in the analysis may introduce bias arising from this exogenous shock and obscure the true effect of HSR connection. Therefore, to rule out this major external disturbance and improve the accuracy of causal identification, this study excludes all observations from 2020 and re-estimates the model. As shown in Column (3) of Table 4, after excluding this special year, the coefficient of HSR connection remains significantly negative, indicating that the negative effect of HSR connection on county economic status remains robust and is not affected by short-term contingencies.

4.2.6 Excluding special county observations

Counties directly administered by provincial governments (PACs) occupy a special position in China's administrative division system, and their administrative authority, fiscal arrangements, and statistical accounting methods differ systematically from those of ordinary counties. Within the framework of this study, such samples may give rise to two types of identification bias. On the one hand, PACs usually enjoy the authority to allocate fiscal resources under direct provincial administration, together

with preferential policies; changes in their shares of provincial GDP are therefore more likely to be driven by administrative intervention than by market mechanisms, which intensifies the endogeneity of the county economic status indicator. On the other hand, the channels through which HSR connection affects PACs may differ: because these counties maintain stronger administrative ties with provincial capitals, the effect of HSR connection is easily masked or distorted by provincial resource redistribution, making it difficult to truly reflect the impact of HSR connection on the county-level economic landscape. Including such special samples in the analysis would undermine sample homogeneity and contaminate the estimation of the net effect of HSR connection. Therefore, to enhance the rigor of model specification and the purity of causal inference, this study strictly excludes all observations of PACs and re-estimates the model focusing on ordinary counties under the jurisdiction of prefecture-level cities. As shown in Column (4) of Table 4, after excluding such special samples, the coefficient of HSR connection remains significantly negative, a result that rules out estimation interference arising from administrative hierarchy.

Table 4

Robustness tests and endogeneity treatment

	Dependent variable: county economic status				
	(1)	(2)	(3)	(4)	(5)
Variable	Replacing the measure of the dependent variable	Incorporating multidimensional interactive fixed effects	Excluding observations from the special period	Excluding special county observations	Endogeneity treatment
$Hsr * Post$	-0.0556*	-0.0547***	-0.0561***	-0.0559***	-0.0984*
	(-1.9152)	(-8.7467)	(-2.9042)	(-2.8283)	(-1.5616)
Are	0.0999*	0.0412**	0.0376	0.0498	0.3541
	(1.8985)	(2.3440)	(0.8181)	(0.9165)	(0.5307)
Pop	0.0327	0.0397***	0.0420	0.0348	-0.1214
	(0.7396)	(5.8446)	(1.4431)	(1.3926)	(-0.4862)
Ser	-1.3704***	-0.6752***	-0.6898***	-0.6444***	-0.5078***
	(-7.2417)	(-31.1216)	(-8.0424)	(-7.8329)	(-2.7017)
Inc	0.2142***	0.1596***	0.1573***	0.1347***	0.0199
	(3.3209)	(26.7536)	(5.8033)	(7.9583)	(0.5832)
Emp	0.0033	0.0293***	0.0302***	0.0284***	0.0788
	(0.3514)	(15.4367)	(3.5948)	(3.4905)	(0.9640)
Constant	-1.6703*	-1.5278***	-1.3717***	-1.2076**	-1.9243
	(-1.6999)	(-9.2588)	(-2.6214)	(-2.3815)	(-0.2823)
$L.Hsr * Post$					0.9297***

					(9.0126)
County FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
AR(1)p					0.0000
AR(2)p					0.3431
Hansen p					0.239
Observations	44573	44622	42837	43872	42837
Adjusted R^2	0.1099	0.8970	0.1794	0.1794	

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Z-statistics are in parentheses.

4.2.7 Endogeneity treatment

Given that county economic development typically exhibits strong path dependence—that is, the current county economic status is often influenced by its lagged level—this dynamic persistence makes it difficult for static panel models to fully capture the underlying patterns of economic activity. Meanwhile, bidirectional causality may exist between the core independent variable, HSR connection, and county economic status. If left unaddressed, the endogeneity arising from such reverse causality would bias the estimation results. In addition, the model may suffer from endogenous interference caused by omitted variables or measurement errors. To effectively address these issues, this study introduces a dynamic panel model and estimates it using the system generalized method of moments (System GMM), thereby conducting a robustness analysis of potential endogeneity. Column (5) of Table 4 reports the estimation results. The results show that, after controlling for endogeneity, the signs and significance of the coefficients remain essentially consistent, indicating that the estimation results are highly robust. Moreover, the AR(1) and AR(2) test results indicate that the disturbance term exhibits first-order autocorrelation but no second-order autocorrelation, and the Hansen statistic of the overidentification test is insignificant. Therefore, the System GMM estimation employed in this study is valid.

4.3. Heterogeneity analysis

To further investigate the heterogeneous effects of HSR connection on county economic status, this study conducts the analysis along six dimensions: the stage of HSR opening, population size, industrialization level, geographic region, natural resource endowments, and tourism resource endowments.

4.3.1. Heterogeneity by HSR opening stage

Before 2008, the development of HSR in China was in a stage of initial exploration and pilot construction. During this period, although China had launched six rounds of national railway speed-up campaigns since 1997 and completed the first HSR line—the Qinhuangdao–Shenyang Passenger Dedicated Line—a genuine HSR network had not yet taken shape. Technical standards were not unified, operational experience was insufficient, and investment was limited; moreover, HSR construction was concentrated

in only a few local areas, and its impact on the regional economic landscape was relatively weak. The year 2008 marked a critical turning point in China's HSR development. On the one hand, the *Mid- and Long-Term Railway Network Plan (2008 Adjustment)* explicitly proposed building the "four vertical and four horizontal" HSR backbone, marking the shift of HSR construction from local pilots to systematic advancement at the national strategic level. On the other hand, the Beijing–Tianjin Intercity HSR officially opened in 2008; as China's first HSR line with a design speed of 350 km/h, it ushered in an era of large-scale, standardized, and networked HSR construction. Thereafter, driven by the four-trillion-yuan economic stimulus package, HSR investment increased substantially, construction accelerated significantly, and network coverage rapidly expanded to China's major city clusters. During this stage, HSR not only physically reshaped the regional spatiotemporal landscape but also profoundly affected factor flows and industrial location, thereby exerting substantial impacts on county economic status.

Accordingly, this study takes 2008 as the dividing point and splits the sample period into two subperiods, 1999–2008 and 2008–2023, and examines the temporal heterogeneity by introducing the interaction term between a time dummy and the core independent variable, so as to test whether the effect of HSR connection on county economic status differs across development stages. The regression results are reported in Columns (1)–(2) of Table 5: the coefficient of HSR connection is significantly negative only after 2008. After China entered the era of large-scale, standardized, and networked HSR construction in 2008, transport costs fell sharply, even bringing counties and central cities into a "one-day living circle", which accelerated the outflow of labor and capital and the loss of land factors through cropland abandonment, while the concentration of high-quality resources in central cities became increasingly pronounced. Although some counties enjoyed improved transport accessibility, they fell into a "corridor economy" predicament—serving merely as passageways rather than reaping substantial benefits.

4.3.2. Heterogeneity by population size

The effect of HSR connection on county economic status is essentially realized by altering the pattern of factor flows, which inevitably diverges with differences in county population size. Moreover, counties of different population sizes differ in development positioning and resource endowments, so the magnitude of the impact of HSR connection on their economic status also varies. Accordingly, pursuant to the *Notice of the State Council on Adjusting the Standards for City Size Classification* (State Council Document [2014] No. 51), which classifies cities into five categories by population size[1], this study—given that the largest of the 1,807 sample counties has a population

[1] Cities with an urban permanent resident population below 500,000 are classified as small cities; those between 500,000 and 1 million as medium-sized cities; those between 1 million and 5 million as large cities; those

of only 2.43 million—focuses on three types of counties, namely small cities, medium-sized cities, and large cities, and conducts the heterogeneity analysis by introducing the interaction term between category dummies and the core independent variable. Column (3) of Table 5 shows that the coefficient of HSR connection is insignificant, whereas Columns (4)–(5) show that the coefficient is significantly negative, with a larger absolute value for large cities.

This indicates that the larger the county population, the stronger the negative effect of HSR connection on its economic status. It is particularly noteworthy that the empirical results also reveal a critical threshold phenomenon: when county population size is too small, HSR connection does not significantly affect county economic status. Counties with very small populations generally suffer from insufficient economic scale and weak industrial foundations, and lack the capacity to retain production factors. A normalized pattern of net factor outflow had already taken shape in these counties before HSR opening, and the marginalization of their economies had already become entrenched, such that the exogenous shock of HSR can hardly bring about significant marginal changes to their economic status.

Table 5

Heterogeneity by HSR opening stage and population size

Variable	Dependent variable: county economic status				
	(1)	(2)	(3)	(4)	(5)
	Pre-2008	Post-2008	Small cities	Medium-sized cities	Large cities
$Hsr * Post$	-0.0415	-0.0541***	0.0033	-0.0805***	-0.1007**
	(-0.6487)	(-2.8127)	(0.1126)	(-3.0891)	(-2.0264)
Are	0.0411	0.0411	0.0410	0.0407	0.0403
	(0.8856)	(0.8914)	(0.8826)	(0.8846)	(0.8691)
Pop	0.0412	0.0397	0.0414	0.0426	0.0434
	(1.5246)	(1.4351)	(1.5118)	(1.5427)	(1.5368)
Ser	-0.6764***	-0.6754***	-0.6765***	-0.6748***	-0.6746***
	(-8.0056)	(-7.9916)	(-8.0173)	(-8.0019)	(-7.9942)
Inc	0.1638***	0.1596***	0.1638***	0.1611***	0.1619***
	(6.1298)	(5.9768)	(6.1351)	(6.0266)	(6.0653)
Emp	0.0290***	0.0293***	0.0290***	0.0292***	0.0292***
	(3.5603)	(3.5633)	(3.5609)	(3.5565)	(3.5728)
Constant	-1.4301***	-1.3823***	-1.4322***	-1.4273***	-1.4396***

between 5 million and 10 million as megacities; and those above 10 million as super-large cities.

	(-2.7954)	(-2.6953)	(-2.8017)	(-2.7815)	(-2.7737)
County FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	44622	44622	44622	44622	44622
Adjusted R^2	0.1957	0.1855	0.1958	0.1900	0.1899

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Z-statistics are in parentheses.

4.3.3. Heterogeneity by industrialization level

The industrialization level of a region not only determines its industrial structure and labor productivity (Clark, 1940; Rostow, 1960; Kuznets, 1966), but also profoundly shapes how the region responds to improvements in transport infrastructure (Fishlow, 1965; Faber, 2014). Counties at different stages of industrialization, owing to differences in their growth drivers, may exhibit markedly different development trajectories when faced with the compression of spatiotemporal distances. Since the reform and opening-up, Chinese cities have differed in resource endowments, policy orientations, and industrial foundations, leading to marked unevenness in their industrialization processes: some are traditional industrial cities that rose rapidly on heavy industry, some are emerging industrial bases that have achieved leapfrog development in light industry by undertaking industrial transfers, and some are less developed regions that have long remained agriculture-dominated due to geographic constraints. Therefore, following Wang et al. (2019) and Yu and Lin (2022), this study measures industrialization level by the share of secondary industry value added in GDP, classifies cities with an industrialization level above 50% as high-industrialization cities and those below 50% as low-industrialization cities, and conducts the heterogeneity analysis across industrialization levels. Columns (1)–(2) of Table 6 show that the coefficient of HSR connection on county economic status is significantly negative only in low-industrialization regions.

Low-industrialization counties are usually dominated by resource-dependent or labor-intensive industries (Hilson, 2009), with short industrial chains, low value-added products, and a lack of leading industries with core competitiveness. The time–space compression effect brought by HSR connection drives production factors in these counties into a net outflow. Moreover, they are at a disadvantage in undertaking industrial spillovers and can hardly form new growth engines to offset the losses caused by factor outflows, causing their economic status to decline in regional competition. High-industrialization regions, by contrast, usually possess relatively complete industrial systems, strong technological innovation capacity, and relatively mature industrial clusters (Porter, 1990), enabling them to effectively absorb technological spillovers (Cohen and Levinthal, 1990). HSR connection further helps these regions enhance technological innovation and expand market potential, strengthening their

capacity to attract factors. The time–space compression effect of HSR thus reshapes the pattern of factor flows in high-industrialization regions into a two-way flow, in which moderate outflows to central cities coexist with industrial spillover and innovation diffusion from central cities. With well-developed industrial supporting facilities, these regions can even occupy a more proactive position in their interactions with central cities; even when facing a certain degree of factor outflow, they can offset the losses through technological innovation and structural upgrading by virtue of industrial resilience, so that their economic status is not weakened by HSR connection.

Table 6

Heterogeneity by industrialization level and region

Variable	Dependent variable: county economic status					
	(1)	(2)	(3)	(4)	(5)	(6)
	Low industrialization	High industrialization	Eastern	Central	Western	Northeast
*Hsr*Post*	-0.0573***	-0.0207	-0.0562**	0.0077	-0.0521	-0.1862***
	(-3.7463)	(-0.4575)	(-2.0400)	(0.2505)	(-0.9786)	(-3.1711)
Are	0.0424	0.0406	0.0423	0.0412	0.0413	0.0409
	(0.9166)	(0.8799)	(0.9126)	(0.8881)	(0.8892)	(0.8834)
Pop	0.0387	0.0416	0.0408	0.0412	0.0405	0.0406
	(1.4214)	(1.5330)	(1.4242)	(1.5241)	(1.5199)	(1.5320)
Ser	-0.6641***	-0.6806***	-0.6779***	-0.6769***	-0.6759***	-0.6767***
	(-7.9017)	(-8.1764)	(-8.0108)	(-8.0166)	(-7.9743)	(-8.0177)
Inc	0.1605***	0.1634***	0.1600***	0.1638***	0.1648***	0.1598***
	(5.9942)	(6.1279)	(5.9476)	(6.1242)	(6.1340)	(5.9986)
Emp	0.0290***	0.0291***	0.0292***	0.0290***	0.0291***	0.0286***
	(3.5516)	(3.5612)	(3.5737)	(3.5483)	(3.5621)	(3.5231)
Constant	-1.3861***	-1.4272***	-1.4072***	-1.4310***	-1.4304***	-1.3862***
	(-2.7060)	(-2.7889)	(-2.6940)	(-2.7973)	(-2.8150)	(-2.7281)

County FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	44622	44622	44622	44622	44622	44622
Adjusted R^2	0.1901	0.1938	0.1915	0.1957	0.1924	0.1861

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Z-statistics are in parentheses.

4.3.4. Heterogeneity by region

China's vast territory entails systematic differences across regions in resource endowments, institutional environments, development stages, and functional roles within the national economic landscape, which also determines that the external shock of HSR connection may produce markedly different effects across regions. Accordingly, following the 2011 classification of the National Bureau of Statistics, this study divides the sample into four major regions—eastern, central, western, and northeastern[1]—to reveal the geographic differences in the effect of HSR connection on county economic status. The regression results are reported in Columns (3)–(6) of Table 6: the coefficient of HSR connection is significantly negative only for eastern and northeastern counties, but insignificant for central and western counties, with a larger absolute value for northeastern counties. This indicates that the negative effect of HSR connection on county economic status exists only in the eastern and northeastern regions and is stronger in the northeast.

As a traditional old industrial base of China, the northeastern region has long formed an industrial structure dominated by heavy and chemical industries, with a disproportionately high share of the state-owned economy. In recent years, the region has been mired in the decline of traditional industries and persistent net population outflows, suffering from weakening development momentum. Against this backdrop, HSR connection has further fueled regional factor outflows: convenient transport conditions have prompted labor and capital—already trending toward outflow—to relocate continuously to more economically dynamic regions such as the Beijing–Tianjin–Hebei region and the Shandong Peninsula. Meanwhile, counties in the northeast suffer from insufficient industrial linkage and weak collaboration with central cities, making it difficult to effectively capture the industrial spillover dividends from central cities, which further aggravates the decline of county economic status.

The eastern region boasts a strong economic foundation and a high degree of marketization, with mature industrial clusters and close-knit economic collaboration

[1] The eastern region comprises Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the central region comprises Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan; the western region comprises Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang; and the northeastern region comprises Liaoning, Jilin, and Heilongjiang.

systems already in place within the region. At the county level, although eastern counties possess a certain foundation for economic development, they remain in a subordinate position—providing supporting and auxiliary functions—within the regional industrial division of labor. HSR connection has substantially compressed the spatiotemporal costs between counties and central cities and removed the original constraints of commuting and transaction costs, prompting high-quality labor, capital, and other high-end factors in counties to accelerate their agglomeration toward central cities.

As an important geographic hub of China, the central region is the core recipient of the country's gradient industrial transfer. On the one hand, counties in the central region remain spatially distant from the developed eastern coastal areas, so the HSR-induced time–space compression effect has not yet enabled large-scale factor outflows. On the other hand, the central region is deeply undertaking industrial transfers from the east, and the well-developed HSR network provides convenient transport support for its integration into the unified national market and for attracting external capital and industrial resources. Meanwhile, central counties have formed solid industrial support based on distinctive agriculture and competitive manufacturing, which effectively buffers the negative shocks arising from HSR-induced factor diversion.

The western region covers a vast territory, with low population density, prominent market segmentation, and long distances between cities, and the overall spatial agglomeration of economic activities remains relatively limited. The HSR network in the west mainly exhibits a "pole–axis" layout radiating outward from provincial capitals as cores, and has not yet formed the mature networked transport pattern seen in the eastern region. Moreover, most counties in the west, relying on distinctive natural resources and ecological function positioning, have formed development models with strong place-bound characteristics and show low dependence on highly mobile manufacturing and services. Meanwhile, the state's sustained policy support and resource preferences for the western region have effectively buffered against the risk of factor loss that HSR connection may trigger. Therefore, the effect of HSR connection on the county economic status of central and western counties has yet to manifest itself.

4.3.5. Heterogeneity by natural resource endowment

A region's natural resource endowments determine its initial industrial development path and its response mechanism to external shocks. Differences in natural resource endowments therefore determine whether, in response to improved transport conditions, a county's economic growth is driven mainly by the deep exploitation of local resources or by opening up to and competing in external markets. Accordingly, pursuant to the *Notice of the State Council on Issuing the National Sustainable Development Plan for Resource-based Cities (2013–2020)* (State Council Document [2013] No. 45), this study divides the sample counties into natural-resource-based and non-natural-resource-based counties for the heterogeneity analysis. Columns (1)–(2) of

Table 7 show that the coefficient of HSR connection is significantly negative only in non-natural-resource-based counties.

Natural-resource-based counties usually possess abundant mineral resources or energy reserves and have formed an industrial structure dominated by resource extraction and primary processing, with their economic development exhibiting strong path dependence. HSR connection directly reduces the outbound transport costs of resource products and expands the market reach, helping achieve scale expansion and efficiency gains. Meanwhile, employment in resource-based industries exhibits a strong local lock-in effect: workers are deeply tied to local and are unlikely to flow out on a large scale as transport becomes more convenient. Even when facing a certain degree of factor attraction from central cities, natural-resource-based counties can rely on the industrial foundation and fiscal revenue built on resource development to maintain a relatively stable development momentum, and their economic status is therefore not significantly weakened. Non-natural-resource-based counties, lacking distinctive natural resource advantages, depend mainly on the agglomeration and market competition of mobile industries such as manufacturing and services. After HSR opening, the compression of spatiotemporal distances substantially lowers the threshold for factor mobility, making local production factors such as labor and capital more easily attracted by regional central cities. In addition, in undertaking industrial spillovers from central cities, these counties face intense competition from other similar counties and can hardly form stable new growth engines. Against this backdrop, HSR mainly serves to accelerate the factors outflow, causing non-natural-resource-based counties to weaken in the pattern of regional competition and thereby undermining their economic status.

Table 7

Heterogeneity by natural and tourism resource endowment

Variable	Dependent variable: county economic status			
	(1)	(2)	(3)	(4)
	Natural-resource-based	Non-natural-resource-based	Tourism-oriented	Non-tourism-oriented
$Hsr * Post$	-0.2068	-0.0346**	-0.0442	-0.0536***
	(-1.2816)	(-2.2232)	(-1.0436)	(-2.5878)
Are	0.0383	0.0416	0.0412	0.0410
	(0.8373)	(0.8983)	(0.8886)	(0.8881)
Pop	0.0413	0.0403	0.0413	0.0397
	(1.5331)	(1.4678)	(1.5267)	(1.4331)
Ser	-0.6738***	-0.6762***	-0.6753***	-0.6768***
	(-7.8926)	(-8.0121)	(-8.0051)	(-8.0114)
Inc	0.1633***	0.1612***	0.1635***	0.1600***

	(6.1217)	(6.0270)	(6.1169)	(5.9960)
Emp	0.0292***	0.0291***	0.0291***	0.0292***
	(3.5844)	(3.5588)	(3.5655)	(3.5579)
Constant	-1.4077***	-1.4035***	-1.4301***	-1.3828***
	(-2.7746)	(-2.7326)	(-2.7969)	(-2.6964)
County FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	44622	44622	44622	44622
Adjusted R^2	0.1833	0.1912	0.1954	0.1858

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Z-statistics are in parentheses.

4.3.6. Heterogeneity by tourism resource endowment

A region's tourism endowments fundamentally define its visitor-oriented, consumption-driven economic patterns. The core effect of HSR connection lies in compressing spatiotemporal distances and reshaping the pattern of factor flows, whereas the presence or absence of tourism resources determines whether a county, when the threshold for visitor inflows is lowered, can effectively capture the dividends of visitor flows and convert them into additional consumption—thereby generating new momentum for economic growth—or is merely reduced to a passageway for factor loss. Accordingly, following Zheng and Kahn (2013) and pursuant to the notices of the Ministry of Culture and Tourism announcing the first and second batches of National All-for-One Tourism Demonstration Zones (Document [2020] No. 83), this study divides the sample counties into tourism-oriented and non-tourism-oriented counties for the heterogeneity analysis, so as to reveal the differences in the effect of HSR connection on county economic status from the perspective of tourism resources. Columns (3)–(4) of Table 7 show that the coefficient of HSR connection is significantly negative only in non-tourism-oriented counties.

Tourism-oriented counties possess distinctive natural landscapes or cultural heritage sites, have formed an industrial structure dominated by hospitality and supporting services, and exhibit a pronounced dependence on inflows of people in their economic development. HSR connection lowers the transport and time costs of tourist travel, causing tourist arrivals from major source markets to surge. The resulting growth in arrivals in turn drives the development of related industries such as accommodation, food and beverage, and retail, offsetting or even outweighing the limited factor outflows that improved transport might induce, so that their county economic status is not adversely affected by HSR connection. In contrast, non-tourism-oriented counties lack the core tourism resources capable of attracting tourists to make dedicated trips. At the same time, without the injection of external consumption brought by tourist inflows, they lack an effective mechanism to compensate for the loss of economic growth momentum when facing factor outflows: local commerce contracts as such inflows decline, and talent migrates out as employment opportunities narrow. On top of this,

unable to benefit from the multiplier effects generated by growing inflows of people, non-tourism-oriented counties are more likely to experience a decline in their county economic status in the HSR era, with their development facing greater headwinds.

5. Mechanism analysis

The results in Columns (1), (3), and (5) of Table 8 show that the coefficients of HSR connection on the mechanism variables are all significantly negative, which verifies the existence of the factor-loss mechanisms of HSR connection through labor and capital outflows as well as cropland abandonment. Hypothesis 2 is thus supported. The results in Columns (2) and (4) of Table 8 show that the coefficients of the interaction term between HSR connection and station location on the mechanism variables are significantly negative, indicating that station location amplifies the labor and capital outflow mechanisms of HSR connection. By contrast, the result in Column (6) of Table 8 shows that the coefficient of the interaction term between HSR connection and station location on the mechanism variable is insignificant, indicating that station location does not significantly affect the land factor loss mechanism associated with cropland abandonment. Hypothesis 4 is thus further supported.

Table 8

Mechanism analysis results.

Variable	Dependent variable: Mechanism variables					
	(1)	(2)	(3)	(4)	(5)	(6)
	Labor outflow		Capital outflow		Land factor loss driven by cropland abandonment	
*Hsr*Post*	-0.0049**	-0.0051	-0.0498***	-0.0425**	-0.1503***	-0.2017***
	(-2.1284)	(-1.6084)	(-4.4186)	(-2.0911)	(-2.8981)	(-2.8156)
*Hsr*Post*Sta*		-0.0810***		-2.7032***		2.6582
		(-2.9256)		(-2.6418)		(0.5280)
Sta		0.0821***		2.6607***		-2.3560
		(3.3222)		(2.6444)		(-0.4672)
Are	-0.0081**	-0.0080**	0.0991	0.0993	1.5020	1.5036
	(-2.3319)	(-2.3246)	(1.6232)	(1.6287)	(1.4852)	(1.4862)
Pop	-0.0962***	-0.0962***	0.0191	0.0188	-0.8370	-0.8356
	(-12.6823)	(-12.6596)	(1.3781)	(1.3610)	(-1.1897)	(-1.1872)
Ser	0.0002	0.0002	0.2375***	0.2375***	0.2091	0.2118
	(0.0400)	(0.0405)	(4.9452)	(4.9421)	(0.6029)	(0.6100)
Inc	-0.0063***	-0.0063***	0.1641***	0.1643***	0.1254	0.1241

	(-9.7160)	(-9.7154)	(9.4002)	(9.4037)	(1.0946)	(1.0827)
Emp	0.1299***	0.1299***	0.0240***	0.0240***	0.0187	0.0189
	(37.4142)	(37.4215)	(4.6285)	(4.6202)	(1.1668)	(1.1764)
Constant	0.1284	0.1284	9.1834***	9.1846***	8.5633***	8.5407***
	(1.2420)	(1.2411)	(16.8623)	(16.8932)	(3.3193)	(3.3102)
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25636	25636	43786	43786	33199	33199
Adjusted R^2	0.7764	0.7764	0.9581	0.9581	0.0797	0.0795

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Z-statistics are in parentheses.

6. Conclusion

Drawing on panel data for 1,807 counties in China spanning 1999 to 2023, this study employs a DID model to empirically examine the effect of HSR connection on county economic status and, from the perspective of transport infrastructure, reveals the underlying causes of the persistent marginalization of county economy and the weak development momentum. The results shows that: (1) HSR connection has reduced county economic status and is a key driver of the persistent marginalization of county economy. This conclusion remains robust after the common trends test, adding control variables, replacing the measure of the dependent variable, incorporating multidimensional interactive fixed effects, excluding observations from the special period and special counties, and endogeneity treatment. (2) Heterogeneity analysis shows that the negative effect of HSR connection on county economic status varies across temporal, regional, and county-characteristic dimensions. Temporally, the negative effect materialized only after 2008, when China advanced large-scale, standardized, and networked HSR construction; regionally, only eastern and northeastern counties are subject to this negative effect, with a stronger effect in the northeast; and in terms of county characteristics, the negative effect is stronger in counties with larger populations but absent in counties with extremely small populations, and exists only in counties with low industrialization levels, non-natural-resource-based counties, and non-tourism-oriented counties. (3) Mechanism analysis reveals that HSR connection reduces county economic status through three pathways: the outflows of labor and capital and the loss of land factors driven by cropland abandonment. (4) HSR station location affects the magnitude of the effect of HSR connection. The closer an HSR station is to the county center, the stronger the negative effect of HSR connection on county economic status. However, the influence of station location is confined to the labor and capital outflow mechanisms and does not affect the land factor loss mechanism associated with cropland abandonment. In other words, shortening the distance between the HSR station and the county center further amplifies the labor and capital outflow mechanisms of counties, thereby intensifying the negative

shock of HSR connection on county economic status. From the perspective of changes in relative economic status and through heterogeneity analysis grounded in the Chinese context, this study contributes more micro-level evidence on the county economic effects of HSR connection, further reveals the mechanisms along the three production-factor dimensions of labor, capital, and land through the lens of endogenous development momentum, and finally attends to the influence of spatial variation in HSR station location. Together, these efforts constitute a substantial addition to the existing literature.

Our study's empirical evidence has the following policy implications. (1) Establish factor retention and offset mechanisms. Specifically, introduce subsidy schemes to support returnee entrepreneurship and local employment, and develop supporting industries aligned with commuting flows to central cities; improve inclusive financial services at the county level and channel local capital toward the real sector; and promote appropriately scaled farming operation and socialized land trusteeship services to mitigate cropland abandonment. (2) Build a regionally coordinated system of targeted differentiated support. Help counties in eastern and northeastern integrate into the central-city-centered industrial chain division of labor and develop complementary industrial roles; support counties in central and western China in leveraging HSR connectivity to undertake industrial transfers and foster indigenous pillar industries; and assist resource-based and tourism-oriented counties in expanding market reach and boosting local retention of production factors. (3) Adopt differentiated approaches to HSR station siting and industrial support. For less industrialized, non-resource-based, and non-tourism-oriented counties, develop industrial transfer parks and returnee entrepreneurship platforms alongside station planning; for counties with extremely small populations and weak industrial bases, indiscriminate pursuit of HSR station placement is inadvisable. Instead, priority should be given to addressing gaps in industrial development and public services.

Our study has several limitations that warrant further exploration. (1) the core independent and mechanism variables are measured with relatively coarse precision. HSR connection is captured solely by a binary dummy variable, without accounting for service-intensity characteristics such as train frequency and travel-time efficiency. As a result, it cannot fully capture the magnitude of the HSR connection shock. For mechanism variables, we use household deposit levels and crop sown area as proxies for capital outflow and cropland abandonment, respectively. These proxies may be confounded by factors such as macroeconomic fluctuations and agricultural restructuring, leaving room for more precise micro-level identification. (2) spatial spillover effects are not fully addressed. Our analysis focuses on counties' relative economic status within their respective provinces, but does not account for cross-provincial or urban-cluster-level spatial interactions. Nor do we employ spatial econometric methods to identify the backwash and agglomeration effects of HSR

connection in neighboring areas. Accordingly, the explanatory power to explain how the national HSR network reshapes county-level economic patterns across China remains limited.

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Data availability

The Stata dataset and replication code supporting this study are uploaded as supplementary files. (1) The county-level high-speed railway opening dataset is compiled via web crawling and manual sorting from sources including the China Railway Yearbook, China Transportation Yearbook, official announcements of China State Railway Group, and authoritative news reports. (2) The geographic data of high-speed railway stations are also obtained through web crawling and manual verification. Based on Amap, we extract the shortest road distance from each county's high-speed railway station to the county center, with the location of the county people's government defined as the county center. (3) The county-level socioeconomic data are primarily sourced from the China Statistical Yearbook, China Regional Economic Statistical Yearbook, and China County Statistical Yearbook. Provincial statistical yearbooks and local statistical communiqués on national economic and social development are further used to fill missing values, so as to construct core variables measuring county economic status and a full set of control variables. Readers may contact the corresponding author for more detailed data upon request.

Ethical Approval

This article does not contain any studies with human participants performed by any of the authors.

Informed Consent

This article does not contain any studies with human participants performed by any of the authors.