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Impact of Urbanization through High-Speed Rail on Regional Development with the Interaction of Socioeconomic Factors: A View of Regional Industrial Structure

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Abstract: This study is to empirically investigate the impact of urbanization through improving transportation infrastructure, reflected by introducing high-speed rail (HSR), on the regional development with the interaction of the socioeconomic factors reflected by industrial structure. An advanced quantitative tool named multi-period difference-in-differences (DID) method is applied. We find the impact of urbanization through HSR on regional development is mixed while interacting with industrial structure helps to explain heterogeneities of the impact. The more the industrial structure tends to be agricultural, the greater the negative impact of HSR opening on regional economic development; meanwhile, the more the industrial structure evolves to be service-oriented, the greater the positive impact of HSR. This study highlights the importance of the interaction between urban growth and socioeconomic factors, which would provides a reference for government and urban planners to make decisions on introducing HSR or improving transportation infrastructure.

Keywords: high-speed rail; regional development; urbanization; industrial structure; socioeconomic factor; Yangtze River Delta

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Citation: Hu, J.; Ma, G.; Shen, C.; Zhou, X. Impact of Urbanization through High-Speed Rail on Regional Development with the Interaction of Socioeconomic Factors: A View of Regional Industrial Structure. *Land* **2022**, *11*, 1790. https://doi.org/10.3390/land11101790

Academic Editor: Tao Liu and Pere Serra

Received: 21 August 2022
Accepted: 10 October 2022
Published: 14 October 2022

1. Introduction

Improving transportation infrastructure to speed up urbanization is a strategy used by many countries in the world. As an important transportation infrastructure, high-speed rail (HSR) has been set up in succession in various developed and developing countries [1]. In the location theory of economic geography, transportation infrastructure is an important driving force for urban spatial expansion [2]. Meanwhile, a large number of studies have found a close relationship between the opening of HSR and urbanization [3,4]. Although HSR was introduced late in China compared with some developed countries, it has experienced a new boom in China [5]. According to the report released by China State Rail Group Co., Ltd. (China Rail), by the end of 2020, the mileage of HSR in mainland China has reached 37,900 km, accounting for more than three-quarters of the total HSR mileage in the world; by 2035, this is planned to reach 70,000 km. In recent years, the Chinese government has successively issued a number of policies to support the development of the HSR industry.

However, HSR construction has not been uniformly favored worldwide. Investment into HSR has been debated in some countries in terms of its feasibility; examples, include HS2 in the United Kingdom, the Dallas Houston HSR Project in the United States, and the TAV project in Italy [6]. In academia, there also has been controversy regarding the impact of HSR on economy and society. For instance, although some studies have reported that HSR promotes regional economic development [7,8], other studies have found that the promoting role of HSR is conditional [9], and that HSR may evenleads to economic disparity [10,11].

Based on the above divergences from industrial and academic circles, it is very important to understand how urbanization through HSR affects regional economic development, what prerequisites HSR requires to promote economic development, and what the impact mechanism is. In industrial economics, the flow of production factors is an important factor in the study of industrial development. The introduction of HSR will accelerate the mobility of labor, distribution of production materials, and exchange of knowledge and skills among cities, thus the improving urban accessibility and affecting the pattern of industrial development [12]. With the rapid development of HSR, more development opportunities will be brought to those cities that have HSRs constructed [13]. Different from the existing literature, this paper attempts to empirically examine the impact of urbanization through HSR on regional economic development from the perspective of industrial structure which is an important socioeconomic factors.

This paper focuses on urbanization through HSRs in the Yangtze River Delta (YRD), China. According to the "Outline of the Regional Integration Development Plan of the Yangtze River Delta" issued by the State Council, the YRD region is officially designated as the whole region of Jiangsu Province, Zhejiang Province, Anhui Province and Shanghai. Figure 1 shows the planning scope of the YRD region. The YRD region has actively promoted the integration process. It is one of the regions with the most active economic development, the highest degree of openness and the strongest innovation ability in China. It is also one of the most mature regions in terms of HSR development. Zhou et al. [14] have pointed out that in the early stage of China's HSR development, the YRD was the region that received the most investment in the HSR projects, which was equivalent to the Beijing-Tianjin-Hebei region, and was one of the regions with the highest accessibility level in China. Figure 2 shows the variation in number of cities with HSRs in this region from 2008 to 2019. Data were obtained from the Chinese Research Data Services. This introduces more complexities into the analysis of the impact of HSR on regional economic development. Meanwhile, the role of industrial structure on the impact of HSR in the regional economic development is also examined.

In this paper, we first examine the impact of HSR on the overall regional economic development of the YRD region, by applying a multi-period difference-in-differences (DID) method. In order to answer our questions better, we conduct the analysis with taking the socioeconomic factors of different regions into consideration; therefore, some important socioeconomic indicators are applied as control variables. Dynamic analysis is necessary in order to judge whether the impact of HSR opening on regional economic development conforms to the normal development trend. This can better reveal the regularity of the impact than static analysis, thereby providing a reliable basis for policy formulation. As the heterogeneity naturally existing in different regions or areas may induce different effects, the heterogeneity analysis is also conducted. The results show that the opening of HSR can significantly promote the overall development of the regional economy of the YRD region. This is consistent with the findings of Chen and Haynes [13], Yao et al. [8], andYao et al. [7]. Through dynamic analysis and heterogeneity analysis, the statistical results demonstrate that the impact of HSR opening on regional economic development has gradually increased over time, and that the impact is heterogeneous, due to differences in city size and the province in which the city is located.

Figure 1. Planning scope for the YRD region (source from Shanghai Daily website).

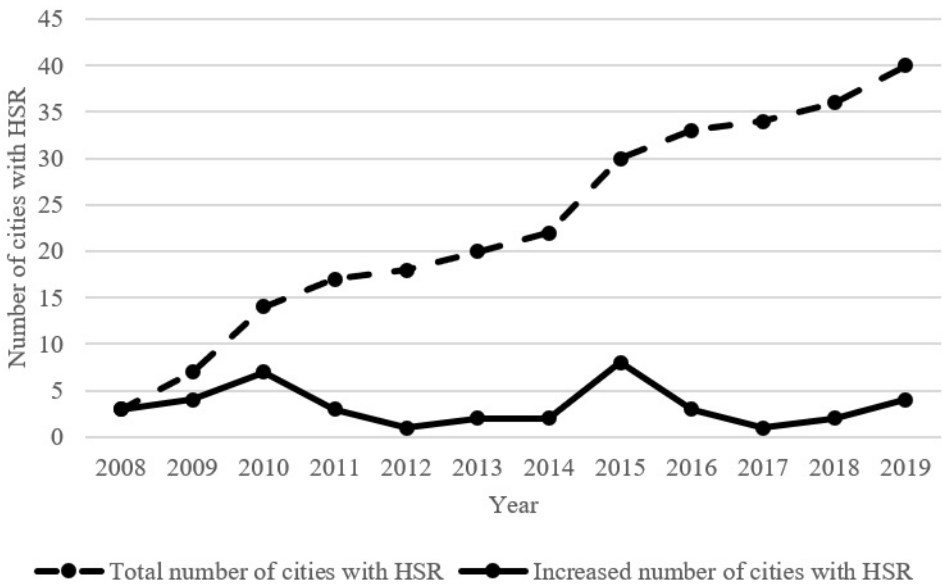

Figure 2. Changes in the number of cities with HSR in the YRD region.

Based on the above research, we focus on the mechanism of the impact of HSR on regional economic development from the perspective of industrial structure. On the basis of the original model, industrial structure and its interaction with HSR opening are introduced. Inspired by the research ideas of Beck et al. [15], we use the initial state of the industrial structure before HSR opening as an indicator of industrial structure. On the ond hand, we can more clearly understand whether the state of the industrial structure before opening the HSR is a pre-requisite for the impact of HSR on regional economic development. On the other hand, it can also help us to understand whether the industrial structure of a city will be affected by HSR and become more advanced or rationalized, thereby affecting the regional economy.

Our research results show that the industrial structure before the opening of HSR will, indeed, affect regional economic development after the opening of HSR. The opening of HSR will inhibit the development of the regional economy in cities that originally rely on primary industries, while the opening of HSR will promote the development of the regional economy in cities that originally rely on secondary and tertiary industries, especially those with more developed tertiary industries. This finding can provide policy suggestions for the planning of HSR development, as well as guidance regarding how to improve the coordinated development of HSR and regional economy from the perspective of industrial development.

The remainder of this paper is organized as follows: the second section of this study reviews the related literature. The third section specifies the used data and methodology. The fourth section analyzes the empirical results. The fifth section provides the results of the robustness tests. The sixth section provides the discusses and in the final section, our conclusions are given.

2. Literature Review

2.1. The Role of the HSR in the Regional Economic Development

Since Aschauer [16] pointed out the importance of public capital (e.g., highways, airports, utilities, mass transit, and water and sewer systems) on the US economy, many studies have further evaluated the economic effect of transportation infrastructure. Moreover, with the development of HSR, studies have begun to focus on the relationship between HSR development and regional economic development. However, the academic community has not yet reached a consistent conclusion regarding the impact of HSR on regional economic development.

Some studies have found that the opening of HSR plays a significant role in promoting regional economic development, driving the economic development of surrounding areas. Kim [17] has described the role of HSR in spatial restructuring and its impact on the pattern of employment opportunities, showing a strong socioeconomic effect of HSR opening. Considering both the benefits and costs associated with HSR (e.g., land-use conversion, output expansion, cost reduction, productivity increase, transport demand substitution and induced demand), Chen et al. [18] have investigated the impact of HSR investment on the economy and environment in China using a computable general equilibrium model and found that the rail investment in China from 2002 to 2013 served as a positive stimulus to the economy at the national level.

Besides, evidence for the convergence effect of HSR on urban economic growth in China has been put forward. Chen and Haynes [13] have found that regional economic disparity was reduced due to the development of HSR. Yao et al. [8] have proposed that HSR appears to have accelerated economic growth by more than 0.6% and the pace of regional economic convergence by approximately 2% per annum over the considered period. Yao et al. [7] have also pointed out that HSR not only accelerates regional economic growth, but also allows initially poor regions to catch up with initially rich ones, leading to regional economic convergence over the considered period. Ahlfeldt and Feddersen [19] have analyzed the economic effects of the Cologne-Frankfurt HSR in Germany and found that the average GDP in the counties of the intermediate stops six years after the opening of the line exceeded a counterfactual trend by 8.5%. They also showed that the benefits delivered by the HSR to the peripheral regions were mediated by knowledge diffusion, labor market pooling, and the effects of improved access to intermediate goods and consumer markets to the extent that the ease of communication reduces transaction costs.

Some studies have confirmed the role of HSR in promoting regional economic development, but also further pointed out that this role is based on certain conditions. For example, Cheng et al. [20] have compared the development of HSR in Europe and China, and found that the impact of HSR on economic development is differed greatly. They found no evidence that HSR would promote economic development unless there was a high degree of integration between HSR networks and regions. Vickerman [21] has pointed out that as a transportation infrastructure investment HSR will have a transformative impact on the economy; this effect will occur when accompanied by other policy interventions. Wang et al. [9] have examined China's four horizontal and four vertical HSR lines, and found that the opening of HSR did not promote the economic growth of cities along the HSR in the short term, but accelerated the economic diffusion of cities along the HSR over time. Long et al. [22] have found that HSR is almost twice as successful in promoting urban expansion in underdeveloped central and Western cities as in developed eastern cities in China. Jia et al. [23] have observed that HSR promotes economic growth, but it has different impacts on different lines.

In contrast, some studies have observed adverse or divergence effects of HSR on regional economy. For example, Gao et al. [24] have found that a HSR connection may impede the local economy. Faber [25] has suggested that improved transport linkages can benefit core regions at the expense of peripheral regions through the introduction of a trade channel. Ke et al. [26] have found that cities in urban agglomerations are more likely to benefit from HSR compared with those not in urban agglomerations. Zhang et al. [11] have also proposed that the opening of HSR has led to a spatial disparity of economic activities, mainly reflected in the aggravation of disparity between cities with and without HSR. Yang et al. [27] have pointed out that the joint intervention of urban agglomerations and the opening of HSR allows more developed areas to siphon resources from less developed areas, resulting in more serious regional economy disparities. Jin et al. [10] have confirmed the positive role of HSR in promoting the overall development of regional economy, while proposing that the heterogeneity of HSR may exacerbate the polarization of China's economy. In the existing literature, there are still mixed conclusions regarding the impact of HSR on economic development. This inspired us to explore the preconditions for the opening of HSR to affect regional economic development, in order to determine the internal factors by which HSR leads to economic divergence or convergence.

2.2. HSR, Industrial Development, and Regional Economic Development

In recent years, some studies have begun to evaluate the impact of HSR on industrial development. First, the findings on the impact of HSR on primary industries have been inconsistent. Li et al. [28] have found the impact of HSR on agriculture to be negligible. Gao et al. [24] have found that HSR connection increased the share of agricultural industry at the prefectural municipal district level. However, Shi and Wang [29] have found that HSR introduction led to a 20.6% increase in cropland abandonment. In hilly and plain areas this proportion is even higher. This indicates that the 'pull' effect brought by HSR may result in a labor force shift from the agricultural sector to other sectors.

Secondly, as for the secondary and tertiary industries, there has also been a lot of research in the academic community. Shao et al. [30], Wang et al. [31] and Li et al. [28] have all found that HSR significantly promoted the agglomeration of service industries in cities along the HSR. Wang et al. [9] have found that China's HSR has not only led to an increase in the proportion of the tertiary industries, but also caused the proportion of secondary industries to decrease. From a perspective of the labor market, Lin [32] has found that industries with higher reliance on non-routine cognitive skills benefit more from HSR-induced market access to other cities. Gao et al. [24] have found HSR connection reduces the share of the secondary industry at the county level by about 2.8%. This finding is consistent with the results of Faber [25], Percoco [33], and Shao et al. [30]. They also found that HSR connection increases the share of service industry at the country level. Jin et al. [34] have found that HSR has significantly promoted the development of ice-snow tourism economy in Northeast China. With data from China's YRD region, Shao et al. [30] find that HSR promotes agglomeration of the producer service industry, particularly with respect to medium- and small-sized cities located on the rail line.

The literature includes more detailed studies on this issue. The impacts of HSR on the industries of core cities and peripheral cities are in opposition. From a perspective of house prices, Zhou and Zhang [35] have observed the house price premium of industrial parks in two important core-periphery city pairs in China: Shanghai-Suzhou and Beijing-Langfang. They found that the premium of service industrial parks (SIPs) has grown faster near HSR stations, while that of manufacturing industrial parks (MIPs) has grown slower near HSR stations in core cities; however, in peripheral cities, this phenomenon is opposite. Therefore, it can be seen that the conclusions on this issue are not completely consistent. There are also some different findings in the existing literature. Cui and Li [36] have found that the HSR will lead to a 9.5% reduction in inventory expenditure of manufacturing firms in China. Li and Xu [37] have observed that after the opening of HSR in Japan, a decline by 7% in service employment and an increase by 21% in manufacturing employment in peripheral areas. In view of the impact of HSR opening on industrial development, although the existing literature has not yet reached a consensus, it inspire this study, as the impact of HSR on regional economic development may be mediated through the channel of industrial structure adjustment.

In the existing literature, only a few studies have linked HSR, industrial structure and regional economic development. Liang et al. [38] have chosen a typical HSR that connects the most-developed eastern region and the less-developed western region in China, in order to examine the role of HSR in the economic growth of less-developed areas. They found no significant regional economic growth along this route and the effectiveness of HSR driving the less-developed area was mainly through the mechanisms of "investment effect" and "industrial structure effect". The method used in the mechanism test involved separating the DID term and the two major effects, respectively. This method can show the impact mechanism of industrial structure on the economic benefits of HSR, but cannot fully reflect the differences of the impact mechanisms of various industries. Gao et al. [24] have found that the impeding effect of HSR connection on the local economy in the YRD region is channeled through population reallocation from peripheral to core areas and industrial restructuring. However, their inspection method did not link HSR, industrial structure and economic development. Although they proved that HSR has an impact on the share of industries, it cannot explain how this impact will affect regional economic development.

These research results provide a theoretical basis and literature support for our research, enabling us to explore the impact of HSR on regional economic development from the perspective of industrial structure, in an attempt to connect them to more accurately measure their internal relationship. This problem is addressed in this paper by designing a more effective research framework, through which we can more clearly understand the impacts of industrial structure differences on the economic benefits of HSR, such that we can put forward more targeted policy recommendations.

3. Data and Methodology

3.1. Basic Specification

The difference-in-differences (DID) method has been commonly used in previous studies to estimate the effect of HSR on the local economy [19,30,32,39,40]. In this study, we use the multi-period DID method, as HSRs are constructed at different times, in order to examine the impact of HSRs on economic development.This method allows selection based on individual characteristics, as long as such characteristics do not change over time which can largely alleviate the endogeneity caused by "selection bias". Fixed effect estimation is applied to alleviate the problem of missing variables. The P-value of Hausman test result was 0.000, which means that the original hypothesis was rejected and indicates that the fixed effect should be used. The specific model was as follows:

$$Y_{jt} = \alpha + \beta HSR_{jt} + \delta X_{jt} + A_j + B_t + \varepsilon_{jt}, j = 1, \ldots, 41; t = 2000, \ldots, 2017, \quad (1)$$

where Y_{jt} is the dependent variable, which represents the economic development level of city j in year t. HSR_{jt} is a dummy variable indicating whether city j has HSR in year t; (if city j has HSR in year t, $HSR_{jt} = 1$; otherwise $HSR_{jt} = 0$); the coefficient β represents the effect of HSR on economic development; X_{jt} represents a series of control variables; A_j and B_t denote the urban fixed effect and time fixed effect, respectively; and ε_{jt} is the error term.

3.2. Variable Selection

3.2.1. Measuring Economic Development Level

We apply economic density as a proxy for economic development level, rather than the commonly used GDP or per capita GDP, based on the following considerations. First, economic density reflects the efficiency of economic activities per unit area and the land-use intensity, which can better reflect the agglomeration degree of regional economic development. According to the theory of economy agglomeration, the larger the economic scale per unit area, the stronger the economic agglomeration effect. Second, economic density can better explain the quality of economic development rather than the total amount of economic growth. The quality of economic development is the real concern of this paper. Third, there is large mobile populations in the YRD region, which has become an important part of the regional economic contribution. As per capita GDP is calculated with respect to the number of permanent residents, using it will ignore the mobile population, resulting in estimation biases.

In this study, the economic density is equal to the ratio of regional real GDP (taking 2000 as the base year) to regional area. Figure 3 shows the economic density of Shanghai City, Zhejiang, Jiangsu, and Anhui Provinces from 2000 to 2017. With the highest efficiency of economic activities per unit area, Shanghai presented the strongest economic agglomeration effect. The economic density of the other three provinces is typically ranked as Jiangsu, Zhejiang and Anhui from high to low.

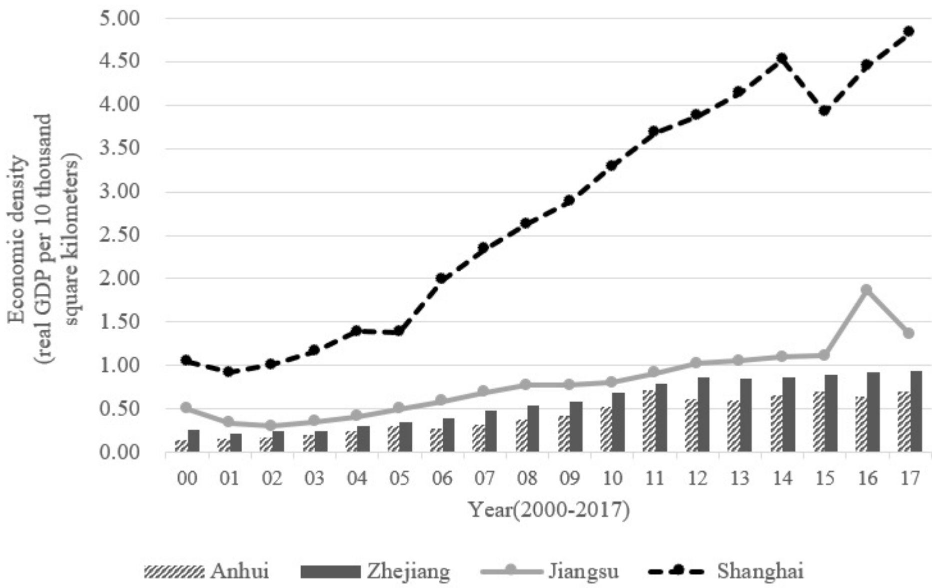

Figure 3. Economic density in the YRD region

3.2.2. Control Variables

Based on the existing literature and data accessibility, the control variables selected in this study include the logarithm of the actual amount of foreign investment as an indicator of the opening-up level, the logarithm of the amount of real estate investment as an indicator of the level of fixed asset investment, the logarithm of the total amount of social consumption as an indicator of the market scale, the ratio of gross domestic product of the tertiary industry to that of the primary industry as an indicator of industrial structure, the ratio of science and technology expenditure to public finance expenditure as an indicator of investment level in science and technology, and the logarithm of annual average wage of employees as an indicator of the income level of employees. The variables in monetary units have been deflated into real variables by taking logarithms. Otherwise, the panel data regression results may be distorted by price level changes across time. The data for economic density and all control variables in the sample were obtained from 'China Urban Statistical Yearbook' over the considered period. The opening years of the HSRs were sourced from relevant announcements disclosed by the national rail administration. The descriptive statistics of each variable are presented in Table 1.

Table 1. Descriptive statistics of main variables.

Variable	Observation Number	Mean	Standard Deviation	Minimum	Maximum	Explanation
Economic density (ED)	738	0.64	0.71	0.01	4.83	Real GDP per 10 thousand square kilometers
HSR	738	0.27	0.44	0.00	1.00	Dummy variable, if HSR opens, HSR = 1, or 0.
Foreign capital	738	9.77	1.98	3.85	14.43	Logarithm of the amount of foreign capital actually utilized
Fixed assets	738	13.34	1.60	9.37	17.47	Logarithm of real estate investment amount
Market scale	738	14.41	1.38	11.41	18.59	logarithm of total social consumption
Industrial structure	738	18.65	24.15	0.37	199.47	Proportion of GDP of the tertiary industry to that of the primary industry
Public finance	738	0.03	0.05	0.00	0.31	Proportion of science and technology expenditure in public finance expenditure
Income	738	3.75	2.27	0.34	13.08	Logarithm of annual average wage of employees

3.3. Dynamic Analysis

The dynamics of the relationship between HSR opening and regional economic development were examined following Beck et al. [15]. A series of time dummy variables were introduced into model (1), in order to test the dynamic impact of HSR on economic development in the years before and after the opening of the HSR.

The specific model was as follows:

$$ED_{jt} = \alpha + \beta_1 D_{jt}^{-8} + \beta_2 D_{jt}^{-7} + \ldots + \beta_{18} D_{jt}^{+9} + A_j + B_t + \varepsilon_{jt} \quad (2)$$

where the dummy variable $D_{jt}^{-n} = 1$ denotes the nth year before the opening of the HSR in city j; otherwise, $D_{jt}^{-n} = 0$; similarly, the dummy variable $D_{jt}^{+n} = 1$ denotes the nth year after the opening of the HSR in the city j, otherwise, $D_{jt}^{+n} = 0$. As we aim to estimate the dynamic impact of HSR on economic development relative to the year of the HSR opening, the year that the HSR was opened was excluded. A_j and B_t are dummy variables representing the fixed effect of city and time, respectively, and ε_{jt} is the error term.

3.4. Heterogeneity Analysis

The uneven spatial distribution of HSR construction and the different levels of urban development may lead to a heterogeneous impact of HSR on economic development. We further examined the model from three aspects: population size, core city or not, and provincial division.

First, according to the classification criteria presented in the 'Notice on Adjusting the Standard of Urban Size Division' issued by the State Council in 2014, we applied the year-end number of registered residents of municipal districts of each city as a proxy for population size. The data were sourced from the 'China Urban Statistical Yearbook'. Cities with a population of more than 1 million in the sample were classified as big cities, while the others were small- and medium-sized cities. Secondly, according to the outline, 27 cities in YRD region were listed as core cities to radiate and drive high-quality development in the YRD region, namely, Shanghai; Nanjing, Wuxi, Changzhou, Suzhou, Nantong, Yangzhou, Zhenjiang, Yancheng, and Taizhou in Jiangsu Province; Hangzhou, Ningbo, Wenzhou, Huzhou, Jiaxing, Shaoxing, Jinhua, Zhoushan, and Taizhou in Zhejiang Province; Hefei, Wuhu, Maanshan, Tongling, Anqing, Chuzhou, Chizhou and Xuancheng in Anhui Province. Accordingly, the samples were divided into core and non-core regions. Thirdly, the YRD region consists of the city of Shanghai and the three provinces of Jiangsu, Zhejiang and Anhui. The heterogeneity of the impact of HSR on economic development was examined among the three provinces.

3.5. Mechanism: Industrial Structure

The large-scale implementation of the HSR network in China provides more convenience for people to travel [41], has reshaped the urban spatial structure and the spatial distribution of economic activities [4] and also improves the transfer efficiency of production factors among regions [42]. The compression of time and transportation costs greatly improves the optimal allocation of resources and enhances interactions between cities [43,44]. In pursuit of cost-saving, small- and medium-sized cities connected with HSR maybe more popular than non-HSR cities when selecting the location of a work site. As such, labor-intensive industries may be transferred from large cities with higher production and operation costs to small and medium-sized cities with relatively lower production and operation costs. Therefore, HSR may also promote the geographical transfer of industries, gradually affecting the local industrial structure.

Additionally, urbanization refers to the process of urban population expansion, urban land expansion to the suburbs, and urban social, economic and technological changes entering the countryside [45]. The construction of HSR has accelerated this process, further occuping agricultural land. More and more of the labor force engaged in agriculture and manufacturing will leave home and enter service industries in cities as a result of the convenience of HSR [46,47]. Therefore, the labor transfer brought by the increased accessibility between cities may also lead to an adjustment of industrial structure. Although academia has not yet reached an agreement on this issue, a large number of studies have found that HSR has different degrees of impact on the development of the three industries.

To examine whether the impact of HSR on regional economic development is caused by the upgrading of industrial structure, we evaluated the impact of HSR on economic development with different initial industrial structure states, following the conceptual framework of Beck et al. [15]. Specifically, if the impact of HSR on economic development varies with differing initial state of industrial structure, we may better understand the impact mechanism of HSR on economic development. Intuitively, if HSR promotes regional economic development through industrial structure upgrading, the impact of HSR on economic development with lower-form industrial structure before the opening of HSR should be greater, while the impact of HSR on economic development with higher-form industrial structure before the opening of HSR should be smaller.

According to Petty Clark Law and the classical theory of industrial structure optimization, with the development of economy and the improvement of per capita national income, the labor force first moves from the primary industry to the secondary industry. When the per capita national income level is further improved, the labor force will move to the tertiary industry. The primary industry is regarded as a low-level form among the three industries. It can be upgraded to secondary and tertiary industries. If the means by which HSR promotes regional economic development is industrial structure upgrading, it is expected that the opening of HSR in cities dominated by primary industry will enhance regional economic development; this impact should be largest among cities with different initial state of industrial structure. The secondary industry is regarded as a higher-level form than the primary industry. It is expected that the economic development brought by the HSR in the cities dominated by secondary industries is positive, but not as great as that in the cities dominated by the primary industry. Finally, the tertiary industry is regarded as a high-level form. It is expected that the economic development brought by the HSR in the cities dominated by the tertiary industries will be less than that in the cities dominated by primary or secondary industries. Accordingly, the following hypotheses were obtained.

Hypothesis 1. *In cities dominated by primary industries, the impact of HSR on economic development is significantly positive.*

Hypothesis 2. *In cities dominated by secondary industry, the impact of HSR on economic development is significantly positive, but less than that in cities dominated by primary industries.*

Hypothesis 3. *In the cities dominated by tertiary industries, the impact of HSR on economic development is less than that in cities dominated by primary and secondary industries.*

Referring to Beck et al. [15], the following model was established.

$$ED_{jt} = \alpha + \beta_1 HSR_{jt} + \beta_2 HSR_{jt} \times Initial_{jt} + \beta_3 Initial_{jt} + A_j + B_t + \varepsilon_{jt} \quad (3)$$

where $Initial_{jt}$ represents the initial industrial structure of the city j in year t. The average proportion of the output value of primary, secondary, and tertiary industries, respectively, in GDP before the opening of HSR was applied to measure the initial state of industrial structure. Related data can be obtained from "China Urban Statistical Yearbook". $HSR_{jt} \times Initial_{jt}$ is the interaction term between the dummy variable of HSR and the initial situation of industrial structure, and the coefficient β_2 represents the impact of the initial state of industrial structure on economic development brought by HSR. Therefore, it can be used to identify whether industrial structure evolution plays an important role in the impact of HSR on economic development.

In addition, the optimization of industrial structure not only occurs via the evolution of industrial structure from a low to high level, but also through the coordinated development of different industries. Therefore, we introduced a proxy for the coordination degree of industrial development; that is, the rationalization of industrial structure. This is applied to examine whether the initial level of rationalization of industrial structure affects the HSR economy.

The rationalization of industrial structure refers to the process through which production factors are rationally allocated, allowing industries to develop harmoniously and bringing economic benefits under the existing technology and resources. It not only reflects the degree of coordinated development among industries, but also reflects the coupling degree of production factor input and output. We measured the rationalization level of industrial structure based on the methodology proposed by Gan et al. [48] which combines the general measurement of structure deviation and re-defines the Theil index proposed by Theil Henri in 1967 [49]. The calculation formula is as follows:

$$TL = \sum_{i=1}^{n=3} \left(\frac{Y_i}{Y}\right) \ln\left(\frac{\frac{Y_i}{L_i}}{\frac{Y}{L}}\right), \quad (4)$$

where Y_i refers to the output value of industry i, Y refers to the total output value of the three industries, L_i refers to the number of employees in industry i, and L refers to the total number of employees in three industries. Related data can be obtained from "China Urban Statistical Yearbook". TL equals 0 if the economy is in equilibrium. It indicates the degree to which the economy deviates from equilibrium and, consequently, the incompatibility of the industrial structure: the higher the TL value, the lower the rationalization of the industrial structure.

Based on previous analysis, if the economic benefits brought by the opening of the HSR are realized by improving the rationalization level of the industrial structure, the cities with more unreasonable initial industrial structure will acquire more economic benefits through the opening of HSR. Accordingly, we expect that a negative relationship exists between the rationalization level of industrial structure and economic development brought by HSR opening. Otherwise, a positive relationship between the two parts will illustrateillustrates that the impact of HSR opening on regional economic development is not mediated through improving the rationalization level of the industrial structure.

Hypothesis 4. *The rationalization level of industrial structure is significantly and negatively related to the economic development brought by HSR.*

Based on Beck et al. [15], model (5) was established to examine the impact mechanism of HSR on economic development in which an interaction term between the dummy variable of HSR opening and the proxy for the rationalization level of industrial development is introduced:

$$ED_{jt} = \alpha + \omega_1 HSR_{jt} + \omega_2 HSR_{jt} \times Rationalization_{jt} + \omega_3 Rationalization_{jt} + A_j + B_t + \varepsilon_{jt} \quad (5)$$

where ED_{jt} represents the economic density of city j in year t, and $Rationalization_{jt}$ is the initial rationalization level of industrial structure of city j in year t. It is measured by the Theil index in Equation (4). The smaller the Theil index, the higher the rationalization level of the industrial structure. $HSR_{jt} \times Rationalization_{jt}$ is the interaction term between the dummy variable of the HSR opening and the initial rationalization level of industrial structure, while the coefficient ω_2 represents the impact of the initial rationalization level of industrial structure on the economic development brought by HSR.

4. Empirical Results and Analysis

4.1. Basic Results

Table 2 reports the basic estimates for the impact of HSR on economic development. As can be seen from the table, there was a positive correlation between HSR and regional economy. When the series of control variables were included gradually, the coefficients of the HSR varied from 0.103 to 0.230, and all maintained a significance level of 5%. In addition, the coefficients of the control variables science and technology investment level, industrial structure, and income level of employees were significantly positive, indicating that vigorously developing science and technology, a higher proportion of the tertiary industry, and higher income level of employees all have a significant role in improving economic development.

4.2. Dynamic Analysis

Figure 4 reports the dynamics of the impact of HSR on economic development, with a 95% confidence interval. This shows that, except for the first year, before the opening of the HSR, the coefficients of the dummy variables of the HSR were insignificant. In the year before the opening of HSR, the coefficient of the dummy variable became positive and significant at the 95% level. This indicates that during the construction period, the introduction of the HSR has already brought an economic agglomeration effect. On one hand, the construction of the HSR itself is a major investment into fixed assets, which is bound to have a significant impact on economic development. On the other hand, the market reaction indicates that the opening of the HSR is good news for regional economic development overall. Some industrial layout, adjustment, and optimization related to HSR construction may have been implemented, due to the opening of HSR.

After opening of the HSR, after the first year, the economic agglomeration effect brought by the HSR is significant at the 95% level. Moreover, as the operation time increases, the impact of HSR on economic development becomes greater. These results illustrate that the impact of HSR on the regional economy is dynamic and significant.

Table 2. The impact of HSR on regional economic development.

Dependent Variable: ED	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HSR	0.255 **	0.230 **	0.120 **	0.112 **	0.103 **	0.109 **	0.118 **
	(0.015)	(0.014)	(0.025)	(0.025)	(0.039)	(0.027)	(0.025)
Public finance		4.520 **	3.642 ***	3.545 ***	3.563 ***	3.376 ***	3.366 ***
		(0.020)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Industrial structure			0.019 ***	0.019 ***	0.018 ***	0.017 ***	0.017 ***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Foreign capital				−5.788	−4.607	−3.307	−3.102
				(0.398)	(0.480)	(0.602)	(0.620)
Fixed assets					−0.061	−0.055	−0.063
					(0.166)	(0.206)	(0.150)
Income						0.078 **	0.076 *
						(0.048)	(0.052)
Market scale							−0.274
							(0.260)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.47	0.51	0.78	0.79	0.79	0.79	0.8
Observation number	738	738	738	738	738	738	738

Notes: This table reports the estimates of the impact of HSR on economic development. The dependent variable is economic density (ED) which is a proxy for regional economic development. The independent variables are described in Table 1 and were introduced into the model successively. The first line of the results reports the marginal effect, and the *p*-values of the estimated coefficients are in brackets. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

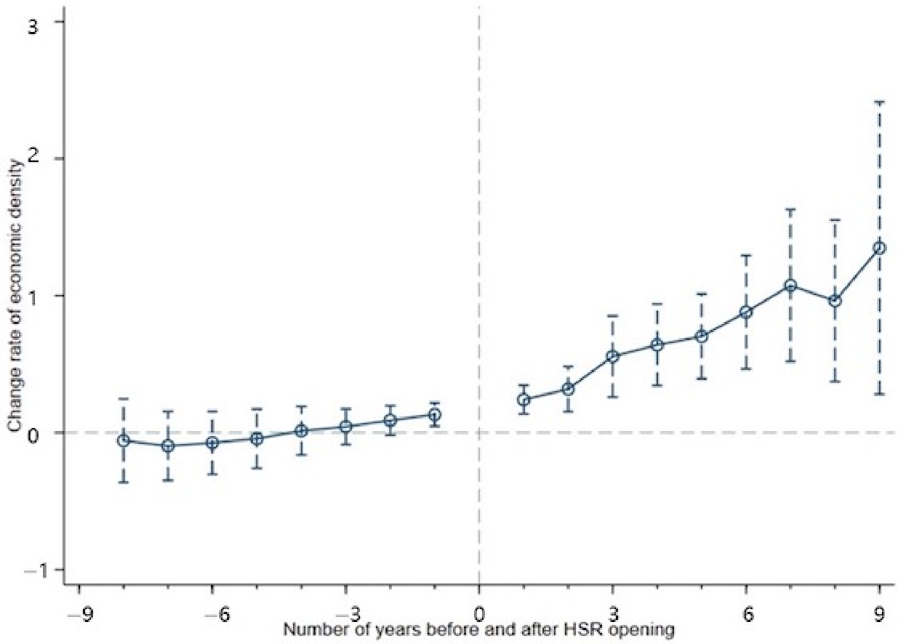

Figure 4. Dynamic impact of HSR on economic development.

4.3. Heterogeneity Analysis

Table 3 reports the heterogeneous impact of HSR on economic development. First, the coefficient of HSR for the sub-region of big cities was 0.112, slightly less than that for the YRD region as a whole. As shown in the table, for big cities, the economic development can be explained more by the fixed asset investment level and the income level of employees, compared with the YRD region. Accordingly, the impact of HSR on the regional economy of large cities will be lesser. The estimation results also indicated that the HSRs in large cities have a significant economic agglomeration effect, while this effect is insignificant in small- and medium-sized cities. This means that the opening of an HSR has led to economic disparity between large cities and small- and medium-sized cities in the YRD region.

Table 3. Heterogeneity analysis of the impact of HSR on economic development.

Dependent Variable: ED	City Size		Central City		Province		
	Big	Small and medium	Central	Non-central	Jiangsu	Zhejiang	Anhui
HSR	0.112 *	0.019	0.08	0.001	0.153 *	0.036	0.082
	(0.068)	(0.714)	(0.240)	(0.979)	(0.090)	(0.617)	(0.442)
Foreign capital	−0.027	0	−0.042	0.004	−0.087 *	0.006	0.012
	(0.309)	(1.000)	(0.253)	(0.705)	(0.089)	(0.908)	(0.622)
Fixed assets	−0.141 **	−0.017	−0.081	0.002	−0.115 **	0.181 **	−0.041
	(0.015)	(0.719)	(0.193)	(0.954)	(0.027)	(0.011)	(0.565)
Industrial structure	0.016 ***	0.017 ***	−0.015 ***	-0.006	0.018 ***	0.029 ***	0.018 ***
	(0.000)	(0.000)	(0.002)	(0.498)	(0.004)	(0.002)	(0.000)
Public finance	3.364 ***	3.114 ***	2.880 ***	2.140 *	1.107	2.12	3.969 ***
	(0.000)	(0.000)	(0.000)	(0.092)	(0.154)	(0.105)	(0.000)
Income	0.090 **	−0.017	0.186 ***	−0.022	0.163 ***	−0.025	0.014
	(0.031)	(0.755)	(0.000)	(0.138)	(0.010)	(0.667)	(0.750)
Market scale	0.078	−0.003	−0.039	−0.062	−0.041	−0.032	0.082
	(0.350)	(0.977)	(0.768)	(0.502)	(0.719)	(0.828)	(0.337)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.85	0.66	0.84	0.62	0.61	0.85	0.73
Observation number	433	305	486	252	270	198	252

Notes: This table reports the estimates of the heterogeneity analysis of the impact of HSR on economic development. The dependent variable is economic density (ED) which is a proxy for regional economic development. The independent variables are described in Table 1. The sample is grouped by city size, core city or not, and provincial division. The first line of the table reports the marginal effects, and the *p*-value of the estimated coefficient is in brackets. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

Second, different from the whole YRD region, the HSRs in core and non-core areas brought positive economic agglomeration effects, but neither were significant. This indicates that for core and non-core cities, the impact of HSR on economic development is negligible, and does not show heterogeneity. The opening of HSR will not have different impacts on the economic development of core and non-core cities and, so it will not aggravate the economic differentiation between core and non-core cities.

Third, the coefficient of HSR for Jiangsu province was 0.153, which was higher than that for the YRD region as a whole. This reveals that in Jiangsu Province the opening of HSR has had a significant impact on its economic development, exceeding the average level for the YRD region. Unlike Jiangsu Province, which is highly sensitive to the opening of HSR, development of the regional economy in Zhejiang and Anhui Provinces was not sensitive to the opening of HSR. The opening of HSR significantly promoted the overall economic development of the YRD region, while the impact of HSR on the economy of different provinces within this region presented heterogeneity, suggesting that the HSR network throughout the YRD region may re-shape the spatial pattern of its regional economic development.

4.4. Mechanism: Industrial Structure

Panel A of Table 4 reports the results of assessing the impact mechanism of HSR on economic development using the proportion of output value of each industry in GDP. Specifically, column (1) shows a significantly negative coefficient on the interaction term, meaning that Hypothesis 1 should be rejected. This indicates that the opening of HSR cannot promote industrial structure evolution of the primary industry to a higher-level form to promote economic development. To the contrary, the introduction of the HSR will inhibit the economic development of such cities. Therefore, cities whose economic development depends on primary industries cannot expect the opening of HSR to promote industrial structure upgrading and economic development. Although the opening of HSR may bring new development opportunities and vitality to these cities, the loss of labor and resources may be more serious at the same time.This finding is consistent with Xu et al. [50] who found that the opening of HSR led to the abandonment of a large amount of cropland and the loss of agricultural workers.

Table 4. Economic effect of HSR and industrial structure.

Panel A. Economic effect of HSR and the proportion of output value of each industry in GDP			
Dependent Variable: ED	**Primary**	**Secondary**	**Tertiary**
HSR	0.847 ***	−0.068	−1.357
	(0.000)	(0.882)	(0.144)
HSR × Initial	−0.037 ***	0.013	0.047 **
	(0.001)	(0.109)	(0.048)
Initial	−0.036 ***	0.023 ***	0.008
	(0.000)	(0.000)	(0.606)
R^2	0.40	0.34	0.38
Observation number	738	738	738
Panel B. Economic effect of HSR and the rationalization level of industrial structure			
HSR	0.739 ***		
	(0.000)		
Rationalization×HSR	0.741 **		
	(0.035)		
Rationalization	0.657		
R^2	0.037		
observation number	738		

Notes: This table reports the results on examining the impact mechanism of HSR on economic development. The dependent variable is economic density (ED) which is a proxy for regional economic development. The interaction term between HSR opening and the initial state of industrial structure is introduced. In Panel A, the initial state of industrial structure is measured by the proportion of output value of each industry in GDP, respectively. In panel B, it is measured by the rationalization level of industrial structure (which is negatively related to TL). The first line of the panel A and panel B reports the marginal effects, and the *p*-value of the estimated coefficient is in brackets. **, and *** represent significance levels of 5%, and 1%, respectively.

The coefficient of the interaction term is insignificant in column (2). This means that the opening of HSR will not bring significant economic development to cities whose economic development originally depended on secondary industries. Therefore, Hypothesis 2 was rejected. The coefficient of the interaction term in column (3) is significantly and positively related to the dependent variable, and is larger than those in columns (1) and (2). Thus, Hypothesis 3 should also be rejected. This finding indicates that, for cities whose economic development depends on tertiary industries before the opening of HSR, the opening of HSR can significantly promote their economic development. These findings imply that upgrading of the industrial structure from a low-level form to a high-level form is not the channel by which HSR opening impacts economic development. For the cities whose economic development depends on the tertiary industries before the opening of HSR, the opening of the HSR will definitely bring economic development; meanwhile, for those cities who rely on primary industries, the opening of HSR will significantly hinder economic development rather than promoting it.

Panel B illustrates the impact of the rationalization level of the industrial structure on the economic effect brought by the opening of HSR.The coefficient of the interaction term is significantly and positively related to the dependent variable, indicating that Hypothesis 4 should be rejected. Therefore, the assumption that the regional economic development brought by the opening of HSR is mediated through improvement of the rationalization level of the industrial structure is not true. The results also showed that cities whose industrial structure tends to be more rational will benefit more, in terms of economic development, from the opening of HSR, which is consistent with the results shown in Table 3.

5. Robustness Tests

5.1. Parallel Trend Test

Considering the randomness of sample selection, the parallel trend test is an important pre-requisite for using the DID method. The research sample covered the period from 2000 to 2017. There was no HSR in the YRD region from 2000 to 2007. Since 2008, the number of cities with HSR has increased. Therefore, the period from 2000 to the year before the opening of the HSR in each city was considered the the period before the policy. Based on Kahn-Lang and Lang [51], the interaction term of year dummy variable and treatment group dummy variable was generated, in order to test whether the coefficient of the interaction term was significant before the opening of the HSR and whether the sample had a parallel trend before the opening of the HSR. If the parallel trend hypothesis is satisfied, it is considered that there is no significant difference in the economic development level between the control group and the treatment group before the opening of the HSR, and whether the HSR is opened or not can be considered random among the cities in the YRD region.

The results of the tests using the leads and the time-trend both indicated that the parallel trend test had been passed. Figure 5 shows that there was no significant difference in economic development level between the control group and the treatment group before the HSR opening, which meets the parallel trend assumption. Therefore, the DID method was considered appropriate to use in this study.

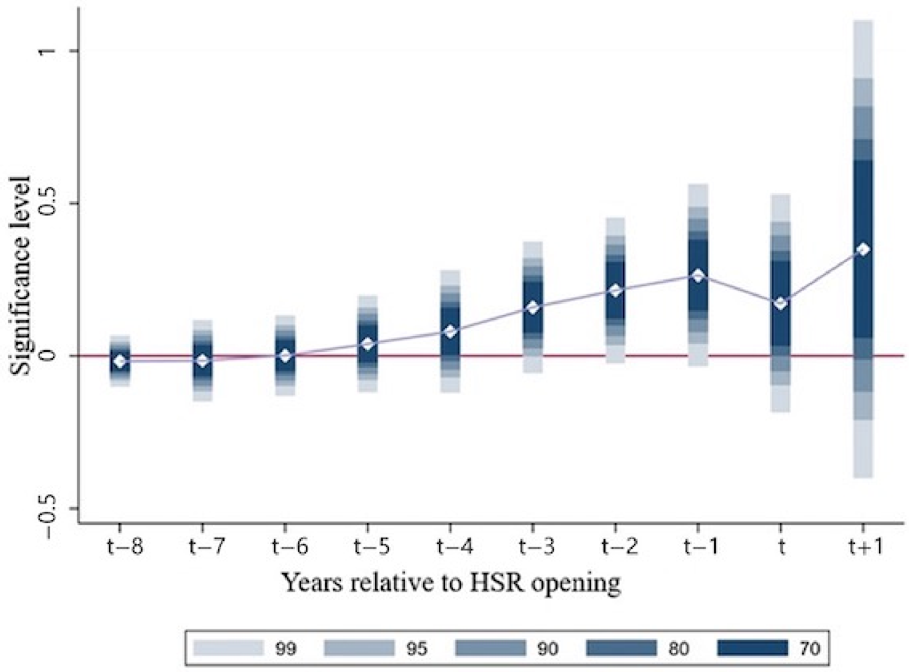

Figure 5. Parallel trend test result.

5.2. Placebo Test

Although the city fixed effect and year fixed effect were controlled in the model, there are other possible explanations for the economic development brought by the HSR. In view of the problem of missing variables, we conducted a placebo test by following Abadie et al. [52]. The policy implementation year was advanced by three, four, or five years; that is, the actual opening year of the HSR was advanced by three, four, or five years as the 'pseudo HSR year'. In this way, three new dummy variables (HSR_3, HSR_4 and HSR_5) were generated. We replaced the dummy variable of the HSR opening in model (1) with these three new virtual variables. If the dummy variable 'pseudo HSR year' had a significant impact on regional economic development, it would indicate that other events occurred at the same time as the HSR opening. To the contrary, the test showed that it was the HSR that had an impact on economic development, rather than other factors. The test results in Table 5 show that the coefficients of the three dummy variables of 'pseudo HSR year' were not significant and, so the placebo test was passed. The empirical results obtained in this study passed both parallel trend test and placebo test, and were therefore robust.

Table 5. Placebo test.

Dependent Variable: ED	(1)	(2)	(3)
HSR_3	0.044		
	(0.420)		
HSR_4		−0.036	
		(0.434)	
HSR_5			−0.073
			(0.199)
Control variables	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes
R^2	0.57	0.57	0.58
Observation number	738	738	738

Notes: The first line of the table reports the marginal effects, and the t-statistics of the estimated coefficients are in brackets.

5.3. Lag Variables

Considering that the opening of the HSR and control variables may have a certain time lag effect on economic development, lag variables were introduced into model (1). All of the independent variables were treated as one phase lag. The results are presented in Table 6. The coefficient of the HSR was still positive and significant, indicating that our analysis was robust.

Table 6. Robustness test—lag variables.

Dependent Variable: ED	(1)	(2)
Lag_HSR	0.365 ***	0.204 **
	(0.003)	(0.002)
Lag_Foreign capital		−3.49
		(0.553)
Lag_Fixed assets		−0.044
		(0.353)
Lag_Industrial structure		0.016 ***
		(0.000)
Lag_Public finance		3.475 ***
		(0.000)
Lag_Income		0.103 **
		(0.036)
Lag_Market scale		−0.383 *
		(0.096)
Time fixed effects	Yes	Yes
City fixed effects	Yes	Yes
R^2	0.49	0.76
Observation number	697	697

Notes: This table reports the results of robustness test. The dependent variable is economic density (ED) which is a proxy for regional economic development. All the independent variables in model (1) were treated as one phase lag. The first line of the panel A and panel B reports the marginal effects, and the *p*-value of the estimated coefficient is in brackets. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

5.4. Subsample Regressions

In order to ensure that the empirical results were not affected by specific regions, we excluded Shanghai, which is the city with the highest primacy in YRD region, as well as cities that had not opened HSR by the end of 2017 (i.e., seven prefecture-level cities, including Bozhou, Fuyang, Huai'an, Lianyungang, Suqian, Yancheng and Zhoushan) and conducted a sensitivity analysis. The results are shown in Table 7. It can be seen that the results did not change when specific cities were excluded. Therefore, the empirical results were robust.

Table 7. Robustness test—sub-samples.

Dependent Variable: ED	Exclude Shanghai		Exclude Non-HSR Cities	
HSR	0.198 **	0.086 *	0.178 *	0.085 *
	(0.026)	(0.080)	(0.077)	(0.091)
Foreign capital		−0.039 *		−0.034
		(0.090)		(0.227)
Fixed assets		−0.018		−0.037
		(0.661)		(0.500)
Industrial structure		0.018 ***		0.017 ***
		(0.000)		(0.000)
Public financesciexp		3.269 ***		3.445 ***
		(0.000)		(0.000)
Income		0.064		0.091 *
		(0.106)		(0.058)
Market scale		0.017		0.01
		(0.803)		(0.903)
Time fixed effects	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
R^2	0.49	0.76	0.48	0.8
Observation number	720	720	612	612

Notes: This table reports the results of robustness test. It excludes Shanghai which is the city with the highest primacy in YRD region and cities that have no HSR by the end of 2017 (i.e., seven prefecture-level cities, including Bozhou, Fuyang, Huai'an, Lianyungang, Suqian, Yancheng and Zhoushan). The first line reports the marginal effects, and the *p*-value of the estimated coefficient is in brackets. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

6. Discussion

The process of China's urbanization is the process of transforming China's rural areas into cities, which relies on the transformation of a large amount of cultivated land into construction land [32,53]. According to the data of the National Bureau of Statistics, from 2000 to 2021, the urbanization rate rose from 36% to 64.72% in China, indicating that it is currently in a period of rapid development. As a large agricultural country with a large population, with the process of urbanization, more and more agricultural practitioners who originally relied on cultivated land flow into cities, and more and more cultivated land resources are occupied or abandoned. Meanwhile, as one of the most-developed countries, in terms of HSR, the development of China's HSR network has greatly increased accessibility between regions, thus speeding up the process of urbanization [22]. Under the urbanization process, the rapid development of HSR has accelerated population migration [54], especially rural-to-urban population migration [55]. This has contributed to the reduction in agricultural practitioners and led to significant cropland abandonment [50,56,57]. Accordingly, these changes have an impact on the adjustment of industrial structure. In the existing literature, a large number of studies have focused on the impact of HSR opening on regional economic development, and have also been focused on the impact of HSR on the development of different industries. However, few studies have considered whether the industrial structure serves as the mechanism mediating the impact of HSR on regional economic development. Clarifying this problem will help to grasp the relationship between HSR implementation, industrial structure, and regional economic development, which is expected to be helpful for HSR project planning, as well as fostering a more targeted industrial structure adjustment to promote regional economic development, in order to maximize the economic benefits of HSR. From both theoretical and empirical aspects, this paper enriches the research on HSR, industrial structure, and regional economic development.

However, there are several limitations to this study, which could be improved in future studies. First of all, the research scope of this paper was limited to the YRD region in China, while several other representative urban areas, such as the Pearl River Delta, or Beijing-Tianjin-Hebei region, may serve as the research objects in future research. They may lead to different research findings from the YRD region, in terms of industrial structure and the impact of HSR on the regional economy. Second, due to the availability of data, this study covered the time range from 2000 to 2017. As shown in the dynamic analysis, the impact of HSR on regional economy enhanced with the increase in time after the opening of HSR. The adjustment of industrial structure is also a gradual process.Therefore, a longer time span may allow the research results to be more accurate. Finally, the research method of this paper was the multi-period DID method. Referring to the design idea of Beck et al. [15], hypotheses were put forward and models were built. This method considers the initial state of the industrial structure of each city before the HSR is opened, and verifies whether the industrial structure mediates the impact of HSR on the regional economy through hypothesis testing. The research results confirmed that the role of HSR in promoting regional economic development is not generated through promoting the industrial structure from a lower to a higher level form. For cities whose economic development depends on tertiary industries, the opening of HSR can promote the development of the regional economy. However, is this promotion a result of the internal optimization of the tertiary industry (e.g., higher resource allocation efficiency and/or the emergence of new industries with and higher added value)? Our research results can not prove this. Additionally, future research may further examine the mechanism by which HSR affects the regional economic development from other perspectives.

7. Conclusions

The main research objective of this paper was to empirically investigate the impact of urbanization through HSR on regional economic development with the interaction of one important socioeconomic factor, which is regional industrial structure. We first examined the overall impact of urbanization through HSR on regional economic development, and conducted a dynamic analysis and heterogeneity analysis of the impact. On this basis, we introduced the proportion of the output of each industry in GDP and the rationalization level of the industrial structure, as well as their respective interactions with the opening of HSR, in order to study whether the impact of HSR on regional economic development is caused by promoting the industrial structure to a higher level form or a more rational development. This research idea refers to Beck et al. [15]. We used the multi-phase DID method and fixed effect method with the data of 41 prefecture-level cities in the YRD region in China from 2000 to 2017. The test results allow us to draw the following conclusions:

(1) The opening of HSR significantly has significantly promoted regional economic development in the YRD region, where the impact is dynamic and heterogeneous. Specifically, the impact appeared one year before the HSR was opened, and was enhanced over time. Compared with other subsamples, the opening of HSR had a more significant impact on the regional economic development of big cities with a population of more than 1 million, as well as in Jiangsu Province overall.

(2) The impact of HSR opening on regional economic development was not generated by promoting the industrial structure to a higher level form or more rational development.

(3) The more the industrial structure tends to be agricultural, the greater the negative economic development brought by the opening of HSR; meanwhile, the more the industrial structure evolves in the service-oriented direction, the greater the economic development brought by the opening of HSR. Specifically, for cities whose economic development depends on primary industries before the opening of HSR, the opening of HSR is expected to inhibit their economic development.For cities whose economic development depends on secondary industries before the opening of HSR, the opening of HSR will have no effect on their economic development. For cities whose economic development depends on tertiary industries before the opening of HSR, the opening of HSR can be expected to improve their economic development.

Our research conclusions provide certain reference for policy-makers. First of all, as an important infrastructure, whether to build HSR requires full consideration of the local industrial structure. Second, HSR is not an investment once and for all: it is necessary to fully consider the impact of industrial structure on the economic benefits of HSR and to adjust the industrial structure in a timely manner, in order to effectively maximize the economic benefits of HSR.

Author Contributions: Conceptualization, J.H., G.M. and C.S.; methodology, G.M. and C.S.; software, G.M.; validation, G.M.; formal analysis, G.M.; investigation, J.H., G.M. and C.S.; resources, J.H. and G.M.; data curation, J.H. and G.M.; writing—original draft preparation, J.H., G.M. and C.S.; writing—review and editing, J.H., G.M., C.S. and X.Z.; visualization, G.M.; supervision, J.H. and C.S.; project administration, J.H. and C.S.; funding acquisition, J.H., C.S. and X.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Shanghai Municipal Foundation for Philosophy and Social Science, grant number 2018ECK007; and Fundamental Research Funds for the Central Universities, grant numbers 2021QKT009, 2021ECNU-YYJ024, 2021ECNU-HWCBFBLW004.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Upon request.

Acknowledgments: All the four authors are first authors, who are alphabetically ordered and contribute equally to the paper.

Conflicts of Interest: The authors declare no conflict of interest.

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