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Research on the impact of China's urban rail transit on economic growth: Based on PSM-DID model

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By the end of 2020, 45 cities in the Chinese mainland operated 244 urban rail transit lines with a total length of 7,969.7 km, Urban rail transit in Chinese cities witnessed a steady growth both in operating scale and passenger traffic in 10 years. Recent studies have explored the environmental and social effects of urban rail transit; however lack in-depth discussion on economic growth. As a quasi-natural experiment, this paper empirically tests the effect of the opening of urban rail transit on urban economic growth based on the panel data of 286 prefecture-level cities in China from 2008 to 2020 and PSM-DID Model. Analysis results show that, rail transit drives urban economic growth. This effect has scale heterogeneity and regional heterogeneity. The findings of this study can provide a valuable reference for the government when it plans the layout of urban rail transit for construction.

KEYWORDS

economic growth, urban rail transit, PSM-DID, policy evaluation, heterogeneity analysis

1 Introduction

According to the seventh national census in 2020, the urbanization rate of China's permanent population has reached 63.89%. The increasing concentration of the urban population and private cars increasingly makes transporting urban residents inconvenient, even resulting in "urban diseases" such as traffic congestion and air pollution. Urban rail transit, however, has the outstanding characteristics of safety, speed, punctuality, and environmental protection. It improves the supply and quality of urban public transport, guides cities to optimize their spatial layout, and strengthens the agglomeration of urban innovation elements. At present, China regards rail transit as the leading future direction of urban public transport development. By the end of 2020, 45 cities in China had opened 244 urban rail transit operation lines, with a total length of 7,969.7 km. Many local governments are competing to develop rail transit for an advantage in urban competition. Constructing and developing urban rail transit in China can alleviate urban diseases and promote urban economic development. However, urban rail transit requires a great deal of financial investment and government subsidies due to its large construction investment scale and high operational costs, which has a negative effect on the stable and sustainable development of the urban economy.

To judge whether the opening of urban rail transit has a facilitating or inhibiting effect on urban economic growth, this paper provides an empirical analysis of 286 prefecture-level cities in China by using the propensity score matching difference-in-differences (PSM-DID) model. The paper demonstrates the impact of the opening of urban rail transit on urban economic development and tests the heterogeneity of cities according to population size and region. The findings show that the opening of urban rail transit plays a significant role in promoting urban economic growth. This promoting effect on the economic growth of large cities is the largest in type II large cities, followed by type I large cities and then super-large cities. The promoting effect on cities is also greater in the central and western regions than in the eastern region. The research conclusions can provide an empirical reference for the government to promote the construction progress of urban rail transit and lay out the urban rail transit system on multiple levels according to different regions and city sizes. The relevant research mainly concentrates on a line in a province or city, such as Beijing (Wang, 2021) and Guangzhou (Liu, 2020). Research on the national urban rail transit economy tends to be theoretical (He, 2017), and empirical research generally uses the production function method (Li, 2017). The possible contributions of this paper are as follows. First, this paper uses a sample of 286 prefecture-level cities, rather than a single city or line, to study the impact of the opening of rail transit on urban economic development. Second, the study takes the opening of rail transit as a quasi-natural experiment and uses the PSM-DID method to evaluate the economic growth effect of the opening of urban rail transit.

2 Literature review

There are many references on the impact of the opening of different types of urban rail transit on the urban economy, including subway, light rail, tram, monorail, and maglev. However, the research conclusions are not consistent.

Most scholars believe that providing urban rail transit can promote development of the urban economy. Huang Changfu and Xia Yuan (2011) analyzed the direct and indirect effect of urban rail transit construction on economic development. Urban rail transit is an important strategy to develop the urban economy, improve a city's industrial structure, and raise citizens' living standards. Daniel and Andrew (2020) found that the population and economic growth of Denver, Salt Lake City, and Portland have exceeded the national average since their rail transit systems became operational. Bardaka et al. (2016) showed the socioeconomic effects of rail transit development. Deyas et al. (2020) showed that Addis Ababa Light Rail Transit has had positive effects on the adjacent residential communities, such as reducing transport costs and travel times and increasing the number of home renters around the light rail transit stations. Woldeamanuel et al. (2022) further showed that Addis Ababa Light Rail Transit provides benefits related to reducing travel distance, travel costs, and traffic problems. Lee (2022) explored differences in the effects of rail transit investment across various types of land with different values and locations along Seoul Metro Line 9, and found that office and apartment lands receive the largest proximity and wider economic benefits that increase their business and development opportunities. Li Zhonghui et al. (2021) found that the construction of urban rail transit infrastructure has a significant positive effect on the factor agglomeration, such as labor force, capital, and technological innovation. And the intermediary effects of factor agglomeration can impact of manufacturing industry and consumer service industry agglomeration.

The completion of rail transit can affect real estate prices, promote the upgrading of industrial structure, improve the accessibility of urban space, and improve the urban environment to promote development of the urban economy. First, the completion of urban rail transit has a significant impact on house prices. Saad and Ardeshir (2019) found that the Dallas–Fort Worth urban rail transit system has had a significant impact on house prices. Using Wuhan as an example, Ronghui Tan et al. (2012) showed that subway stations can significantly improve the house prices in nearby areas. Besides, the urban rail transit industry can drive the rapid development of relevant industries in the region during the construction investment period (Xu, 2012), especially the employment density of secondary and tertiary industries (Deng, 2014). Rail transit can also shorten people's commuting times and reduce travel costs. Sajeeb and Sun (2022) evaluated the comparative advantages of rail transit over taxis in terms of travel cost and time using open data from two American cities. They found that rail transit can be better marketed by highlighting its relative advantage over taxis in travel time and cost, especially for travel in certain directions and at certain times. Gopal and Shin (2019) revealed that the Delhi Metro provides a comparatively empowering and positive travel experience for women, mainly due to safety measures and women's relative sense of safety in transit compared with other public spaces. Urban rail transit can also alleviate urban diseases and promote sustainable and green urban development. Sun et al. (2019) found that rail transit reduces air pollution in the long run, while the construction of rail transit has a negative short-term effect on air quality. Sun and Li (2021) showed that the opening of high-speed railway can significantly reduce the carbon emissions of cities along the route. Michael (2021) found that bus rapid transit is the best option for the area because it is far less expensive, and can provide a more equitable service than light or heavy rail.

Some scholars believe that rail transit may have a negative impact on urban economic development, which would place great financial pressure on the government due to the need for business subsidies. Xue et al. (2015) found that subway construction has a negative effect on residents' travel, transportation, environment, and daily life in China. Tornabene and Nilsson (2021) verified that small business owners faced economic development challenges during the construction phase of a new light rail line in Charlotte, North Carolina, and that these challenges have continued beyond the construction phase. The completion of rail transit may also bring geographical isolation due to the separation of adjacent houses. Deyas et al. (2020) found that LRT lines segregate residents living on opposite sides of the line as a result of infrastructure built above the ground.

Based on the above discussion, the current research mainly analyzes a line or a city. There is little empirical evidence about the Urban Rail Transit effect on economic development by PSM-DID Model. Hence, this study uses the model to estimate the impact of opened urban rail transit based on the panel data of 286 prefecture-level cities in China from 2008 to 2020. It confirms the impact of urban rail transit on economic development. Based on this, the heterogeneity of the effect on the different cities is analyzed, providing a more robust empirical support for the economic development effect caused by the opening of urban rail transit.

3 Empirical design

3.1 Model setup

Choosing whether to open urban rail transit leads to sample self-selection. Therefore, this paper first uses PSM to eliminate the sample self-selection error. This method ensures that the characteristics of the cities in the experimental group and the control group are as similar as possible, except for opening or not opening rail transit. Thereafter, the paper uses the DID model to estimate the impact of rail transit on urban economic development.

According to the above analysis, this paper constructs the formula based on DID as follows:

$$Y_{it} = \alpha + \beta_1 G_i + \beta_2 D_{it} + \gamma X_{it} + \eta_i + \varphi_t + \varepsilon_{it} \tag{1}$$

Further, Eq. 2 uses PSM to find the control group with the most similar characteristics to the experimental group and then uses the matched experimental group and control group for DID regression.

$$Y_{it} \overset{PSM}{=} \alpha + \beta_1 G_i + \beta_2 D_{it} + \gamma X_{it} + \eta_i + \varphi_t + \varepsilon_{it} \tag{2}$$

where the explained variable Y_{it} represents the economic growth rate of City i in year t. X_{it} represents the control variables, including *per capita* GDP, degree of industrial upgrading, government expenditure or government scale, urbanization level, fixed asset investment, and actual foreign investment. The core explanatory variable Gi indicates whether City i opens rail transit during the sample period. It is equal to 1 if City i opens rail transit during the sample period and otherwise equal to 0. D_{it} is the interactive term of grouping virtual variables and city virtual variables. It is used to identify whether a city has opened rail transit in or before year t. A value of 1 is assigned if the city opens rail in the current year and in the years following the opening. A value of 0 is also assigned to the cities that do not open rail transit during the sample period (i.e., the control group). η_i is the individual fixed effect. φ_t is the time fixed effect. ε_{it} is a random perturbation term.

3.2 Explanation of variables

To ensure that the statistical caliber is consistent, this paper selects prefecture-level cities in China from 2008 to 2020 as the main investigation object. The data are obtained from the China Statistical Yearbook, China Urban Statistical Yearbook, and China Urban Construction Statistical Yearbook. The following steps are taken to solve the problem of the lack and homogeneity of data. 1) The cities that do not include economic data in the yearbooks are eliminated. 2) Considering the imbalance of the panel data caused by the withdrawal of counties and cities and the merging of cities, the following cities are deleted: Chaohu, Bijie, Tongren, Sansha, Haidong, Kunshan, Danzhou, Shigatse, Changdu, Nyingchi, Shannan, Turpan, Hami, Naqu, Shenhe, Xiuzhou, and Maizhuang. Applying these steps leads to 286 groups of balanced panel data with a total of 3,718 observations.

The explained variable is urban economic growth, expressed by the real GDP growth rate. The following factors can affect urban economic development: 1) *per capita* GDP, expressed as real *per capita* GDP; 2) industrial upgrading degree, expressed as the proportion of the sum of the added value of the secondary and tertiary industries in GDP; 3) government expenditure, expressed in terms of government public financial expenditure; 4) urbanization level, expressed as the proportion of urban population in relation to the total population; 5) fixed asset investment, which refers to the amount of fixed asset investment in the construction of municipal public facilities and is reduced by the price index of fixed asset investment; 6) foreign direct investment, which is first converted by the exchange rate of RMB to US dollar and then reduced by the GDP index. The above explained variable and control variables are expressed as the logarithms of their values. The descriptive statistics of the variables are shown in Table 1.

4 Empirical results

4.1 Preliminary inspection

Table 2 shows the results of the panel data regression. Column (1) indicates the changes in urban economic growth caused by the opening of rail transit without adding the control variables. Column (2) indicates changes in the urban economy caused by the opening of rail transit in different years without adding the control variables. Columns (3) and (4) indicate the experimental results after adding the control variables to columns (1) and (2), respectively.

Columns (1) and (3) indicate that cities with rail transit have more significant economic growth from 2008 to 2020. Column (2) shows that without adding the control variables, the opening of urban rail transit seems to have no obvious effect on the urban economy in different periods, or even seems to reduce urban economic development. Column (4) shows that after adding other control variables, the coefficient of the core explanatory variable D turns positive and is significant at the 1% level. This shows that the opening of rail transit significantly improves urban economic growth. The coefficients of the urbanization level is significantly negative, consistent with the long-term convergence of the regional economy in the neoclassical economic growth model. The coefficient of government expenditure is negative, which may be due to the crowding-out effect of government public financial expenditure. The estimated coefficients of industrial upgrading, fixed asset investment, and foreign actual investment are significantly positive, consistent with the forecast.

4.2 Inspection based on the PSM-DID method

To overcome systematic differences between cities with rail transit and reduce the estimation error of the DID method, the PSM-DID method is further used for robustness tests. Through the virtual variable of choosing whether to open rail transit, the tendency score value is obtained by logit regression of the control variable, after which the cities in the experimental group are matched with the cities in the control group with the most similar scores. Table 3 shows the logit regression results, indicating that the control variables have strong explanatory power over the treatment variables.

Before PSM-DID estimation, the common support hypothesis needs to be tested to verify the model's effectiveness. This test makes it possible to judge whether the distribution of the variables in the matched experimental group and the control group is balanced. The results of the common support hypothesis test in Table 4 show that there is no significant difference between the matched variables. This difference is somewhat non-eliminable. In addition, there is a significant difference in the mean values of the explained variable, economic growth. Between the experimental group and the control group, while there is little difference between the mean values of the other variables. This finding proves that the PSM-DID method used in this paper is reasonable.

In this paper, the kernel matching method is used in PSM. Figure 1 shows the figure before matching on the left and the figure after

TABLE 1 Descriptive statistics.

Variable name	Abbreviation	Observed value	Mean value	Standard deviation	Minimum value	Maximum value
Economic growth	EG	3,718	2.418	0.502	−2.303	4.691
G	G	3,718	0.157	0.364	0	1
D	D	3,718	0.084	0.278	0	1
Per capita GDP	AGDP	3,718	9.801	0.980	−0.996	14.712
Industrial upgrading degree	IUD	3,718	4.473	0.307	−0.034	8.924
Government expenditure	GE	3,718	14.374	1.032	−1.313	18.312
Urbanization level	UL	3,718	3.347	0.679	−0.341	4.665
Fixed asset investment	FAI	3,718	11.524	1.604	−6.079	16.190
Foreign direct investment	FDI	3,718	11.170	1.842	−2.551	19.733

Note: The above table shows the descriptive statistics for the urban rail transit opening data and the corresponding variables.
Source: Author's estimation.

TABLE 2 Effect of rail transit on urban economic growth.

Explanatory variable	EG	EG	EG	EG
	(1)	(2)	(3)	(4)
G	0.676*** (5.38)		0.624*** (8.36)	
D		−0.069 (−1.36)		0.165** (2.53)
AGDP			0.019** (2.24)	0.019** (2.39)
IUD			0.068 (1.32)	0.063** (2.19)
GE			−0.285*** (−6.17)	−0.293*** (−6.00)
UL			−0.096*** (−3.92)	−0.078*** (−2.98)
FAI			0.053** (2.38)	0.061*** (2.72)
FDI			0.042*** (4.5)	0.046*** (4.76)
_cons	2.327*** (138.15)	2.424*** (568.45)	5.169*** (7.57)	5.187*** (7.49)

Note: *, **, and *** represent significance at the passing 10%, 5%, and 1% levels, respectively. The bracketed numbers are the t-values of the estimations. Source: Author's estimation.

TABLE 3 Logit regression analysis of treatment variables on control variables.

Variables	D	Standard deviation	Z-value	*p*-value
AGDP	−0.380	0.076	−4.96	0.000***
IUD	−0.751	0.329	−2.28	0.022**
GE	2.712	0.179	11.25	0.000***
UL	2.292	0.225	9.92	0.000***
FAI	0.619	0.133	5.70	0.000***
FDI	0.254	0.081	3.16	0.002***

Note: *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively. Source: Author's estimation.

matching on the right. The figures show that the probability density of the propensity score value is closer after matching, indicating that the matching effect is good and further showing the feasibility and rationality of the PSM-DID method used in this paper.

The PSM-DID method is applied to demonstrate the impact of rail transit on urban economic growth. The results are shown in Table 5. The conclusion is consistent with previous findings that the opening of rail transit can significantly promote urban economic growth, and all three differential results are significant at the 1% level.

TABLE 4 Applicability test of the PSM-DID method (common support hypothesis).

Variables	Control group mean	Experimental group mean	Difference	T-value	*p*-value
EG	2.107	2.867	0.760	13.81	0.000***
AGDP	10.464	10.531	0.067	0.70	0.486
IUD	4.558	4.563	0.005	0.65	0.515
GE	14.678	14.707	0.029	1.12	0.261
UL	3.956	3.957	0.001	0.05	0.961
FAI	13.966	13.790	−0.176	1.13	0.263
FDI	13.304	12.972	−0.331	1.37	0.1745

Note: *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively. The bracketed numbers are the t-values of the estimations. Source:Author's estimation.

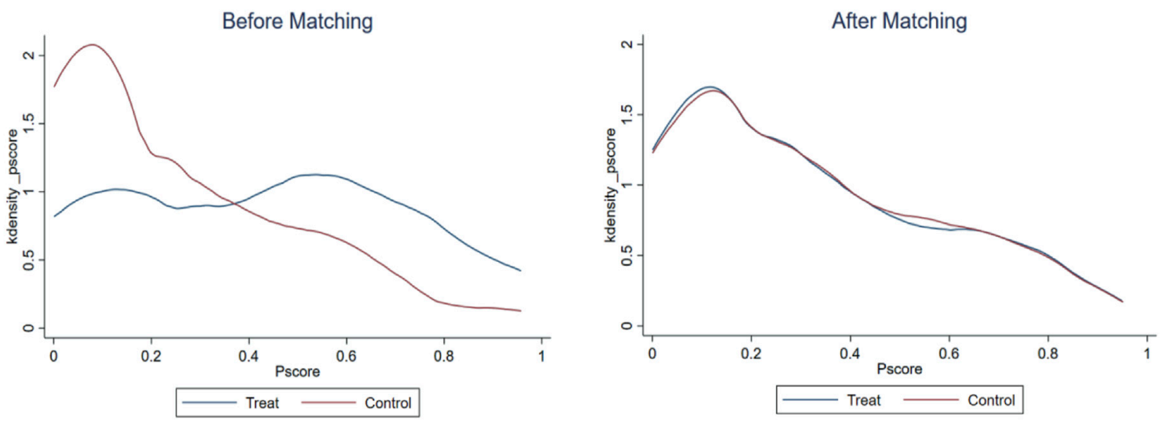

FIGURE 1
Probability distribution density function of the propensity score value. Source: Author's estimation.

TABLE 5 Results of PSM-DID robustness test.

	Difference between experimental group and control group before rail transit opening	Difference between experimental group and control group after rail transit opening	Difference-in-difference result
Difference value	0.312	0.563	0.251
Standard error	0.019	0.044	0.089
T-value	13.66	17.38	14.25
p-value	0.000***	0.000***	0.000***

Note: *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively. Source:Author's estimation.

4.3 Further robustness tests

The first additional robustness test observes the sensitivity of a policy to time changes by changing the time window. This paper studies the impact of the opening of urban rail transit on the urban economy from 2008 to 2020. Taking 2014 as the midpoint, this paper regresses the samples with a wide window of 2, 4, or 6 years around the midpoint. The results in Table 6 show that the window width has no significant effect on the regression coefficient and significance.

Based on the above test, the counterfactual test method is further used. That is, if the opening year of urban rail transit is 1 or 2 years ahead of schedule and the policy treatment effect is still significant, then the urban economic growth is mainly due to other policies or factors. As urban rail transit was opened in Beijing, Tianjin, Shanghai, Guangzhou, Changchun, Dalian, Wuhan, Shenzhen, Chongqing, and Nanjing in or before 2008, these ten cities were removed. Taking 2014 in Table 7 as an example, removing the cities that opened rail transit in or before 2014, then observing the significance of the core explanatory variable D. The results show that the core explanatory

TABLE 6 Effect of different time window widths.

	(1)	(2)	(3)
	One year before and after	Two years before and after	Three years before and after
d	0.118* (0.09)	0.112** (0.06)	0.187*** (0.05)
AGDP	−0.109** (0.04)	−0.172*** (0.03)	−0.172*** (0.03)
IUD	0.079 (0.05)	0.069 (0.04)	0.059 (0.04)
GE	−0.206*** (0.08)	−0.130*** (0.02)	−0.161*** (0.02)
UL	−0.061 (0.04)	−0.019 (0.02)	−0.043** (0.02)
FAI	0.047** (0.07)	0.039*** (0.03)	0.047*** (0.03)
FDI	0.039* (0.02)	0.0282** (0.01)	0.061*** (0.01)
N	804	1,335	1857
F	3.564	13.994	30.961

Note: *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively. The bracketed figures are the standard deviations. Source: Author's estimation.

TABLE 7 Counterfactual test.

Year	(1)	(2)	(3)	4)	5)
	2008	2012	2014	2016	2018
D	−0.030 (−0.23)	0.056 (1.35)	0.056 (1.35)	0.065 (0.97)	0.153* (1.91)
AGDP	0.057* (1.83)	0.025** (2.25)	0.025** (2.25)	0.030** (2.56)	0.041*** (3.21)
IUD	0.007 (0.27)	0.012 (0.73)	0.012 (0.73)	0.015 (0.83)	0.006 (0.33)
GE	−0.110*** (−2.83)	0.127*** (8.42)	0.127*** (8.42)	0.130*** (8.13)	0.146*** (8.00)
UL	0.005 (0.25)	0.164*** (18.55)	0.164*** (18.55)	0.168*** (17.71)	0.164*** (15.86)
FAI	0.114*** (3.27)	0.113*** (7.76)	0.113*** (7.76)	0.109*** (7.19)	0.086*** (4.96)
FDI	−0.002 (−0.26)	−0.004 (−0.45)	−0.041*** (−3.95)	−0.027 (−1.36)	0.016 (0.58)

Note: *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively. The bracketed numbers are the t-values of the estimations. Source: Author's estimation.

variable D is not significant in the selected years, indicating that the growth of the urban economy is caused by the opening of rail transit.

4.4 Heterogeneity analysis of rail transit affecting urban economic growth

4.4.1 Population size heterogeneity analysis

The above empirical analysis shows that the opening of rail transit can improve the urban GDP growth rate. For cities of different sizes, does the promoting effect of rail transit opening on economic growth still exist?

To study the urban scale heterogeneity effect of rail transit on urban economic growth, we first classify the cities by size. According to the notice on adjusting the criteria for the division of city size (GF [2014] No. 51), cities are divided into three categories according to the permanent population: 1) small cities (a population of less than or equal to half a million), 2) medium cities (a population of more than half a million and up to 1 million), and 3) large cities (a population of more than 1 million). Large cities are subdivided into three categories. The specific judgment criteria and the number of relevant cities are shown in Table 8.

Generally, the cities with rail transit are large cities with resident populations of more than 1 million. Therefore, the scale heterogeneity analysis mainly includes large cities. The empirical results are shown in Table 9. In large cities, the coefficients of the core explanatory variable D are positive, indicating that the opening of rail transit in large cities has the effect of promoting economic growth, but the effect differs. Li, (2017) also pointed out that urban rail transit plays a great role in promoting the economic growth of big cities. There is small difference wiht Xu (2018). Based on the method of cluster analys, Xu (2018) classify the economic development status of the 28 cities with completed rail transit and the development of rail transit, the classification results are roughly the same. The specific analysis shows that if the urban population is larger in large cities, the economic promotion effect brought by the opening of rail transit is relatively small. The promotion effect of the opening of rail transit on the economy is the largest in type II large cities, followed by type I large cities and then super-large cities. This finding shows that for large cities, the marginal scale returns of the opening of rail transit decreases. Zhang (2020) also find that metro systems have an economically significant positive effect on the urban GDP growth rate and that this effect is much larger for megacities with permanent populations of more than 6.15 million.

10.3389/fenvs.2023.1082567

TABLE 8 Urban scale division.

City type		Judgment criteria	Number of cities
Small city		≤500,000	629
Medium city		500,001–1,000,000	1,316
Large city	Type II large city	1,000,001–3,000,000	1,433
	Type I large city	3,000,001–5,000,000	139
	Super-large city	>5,000,000	169

Source: The notice on adjusting the criteria for the division of city size (GF [2014] No. 51) Statistics.

TABLE 9 Population size heterogeneity analysis.

	(1)	(2)	(3)
	Type II large cities	Type I large cities	Super-large cities
D	0.214*** (0.05)	0.209*** (0.06)	0.166* (0.09)
AGDP	−0.135*** (0.03)	−0.132*** (0.03)	−0.090** (0.04)
IUD	0.068 (0.04)	0.074* (0.04)	0.078 (0.05)
GE	−0.122*** (0.02)	−0.084*** (0.02)	−0.144* (0.08)
UL	−0.026 (0.02)	−0.009 (0.02)	−0.040 (0.04)
FAI	−0.049* (0.03)	−0.070** (0.03)	−0.005 (0.07)
FDI	0.048*** (0.01)	0.014 (0.01)	0.025 (0.02)

Note: *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively. The bracketed figures are the standard deviations. Source: Author's estimation.

TABLE 10 Regional distribution heterogeneity analysis.

	(1)	(2)	(3)
	Eastern region	Central region	Western region
D	0.012 (0.26)	0.104*** (4.08)	0.118* (1.68)
AGDP	−0.058*** (−3.42)	−0.009 (−0.41)	0.031 (0.96)
IUD	0.049 (1.09)	−0.155** (−2.52)	0.027 (0.68)
GE	−0.189*** (−15.35)	−0.247*** (−12.20)	−0.289*** (−11.56)
UL	−0.060*** (−3.34)	−0.124*** (−5.39)	−0.189*** (−5.66)
FAI	0.012 (1.15)	0.047*** (3.61)	0.036** (2.36)
FDI	0.078*** (8.66)	0.037*** (3.21)	0.023** (2.57)
Number of samples	1,289	1,239	888
Number of sections	190	188	128

Note: *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively. The bracketed numbers are the t-values of the estimations. Source: Author's estimation.

4.4.2 Regional distribution heterogeneity analysis

The regional heterogeneity of the effect of the opening of rail transit on urban economic growth is further analyzed. China's cities are divided into the eastern, central, and western regions. Inner Mongolia and Guangxi are included in the western region. The results are shown in Table 10.

The regression coefficients of the corresponding models in the central and western regions are significant, indicating that the opening of urban rail transit can better promote economic development in the central and western regions than in the eastern region. This may be because rail transit in the eastern region was opened earlier, other transportation modes are relatively superior, and the improvement of some edge lines has no obvious enhancing effect on urban economic growth. The urban traffic foundation in the western and central regions is weak. Currently, the 5 provincial capitals of Taiyuan, Hohhot, Lhasa, Yinchuan, and Xining have not yet opened subways or only opened subways in 2020, but these cities also has a large growth space. In addition, the central and western regions have a relatively backward economy and imperfect transportation infrastructure. The construction of relevant rail transit will thus significantly stimulate the economy. The opening of rail transit in these large cities in central and western China can promote resource allocation and economic growth.

5 Research conclusion and countermeasures

This study uses the panel data of 286 prefecture-level cities in China from 2008 to 2020 and the PSM-DID model estimation method to test the effect of the opening of rail transit on economic growth. The paper further analyzes the heterogeneity of the effects between cities with different population sizes and in different regions. It is found that the economic growth of urban areas with rail transit is indeed faster than other areas in the sample when the remaining conditions are the same. From the perspective of urban scale heterogeneity, the economic growth effect of rail transit is most significant in large cities with an urban population of more than 1 million and less than 5 million. Among these cities, the promotion effect of rail transit on economy is the largest in type II large cities, followed by type I large cities and then super-large cities. From the perspective of regional distribution heterogeneity, the opening of urban rail transit has a stronger pulling effect on urban economic growth in the central and western regions than in the eastern region.

Based on the above research conclusions, the following suggestions are put forward. 1) Each city should steadily promote the construction of urban rail transit according to its ability to develop. This will promote the construction of rail transit in cities where citizens demand transportation and where the government's financial resources can support it. It will also prevent problems such as excessive over-planning and over-concentration of the construction scale. This suggestion will also help avoid a situation where the required fiscal revenue is unavailable, but there is a delusion that urban rail transit will promote real estate to make up for the fiscal expenditure. Finally, this suggestion will help avoid a situation where there is no actual traffic demand but rail transit construction projects are launched blindly to improve the city's image and the appearance of leadership performance. 2) To promote regional synergistic development, relevant departments should actively support the construction of rail transit in large and medium cities in the central and western regions of China to achieve the full driving effect of these cities in inland areas. The transportation infrastructure construction and the density of urban transportation networks in central and western cities are relatively weak, so rail transit construction can make up for the shortcomings and improve the efficiency of traffic. The urbanization rate of the central and western regions is also lower than that in the eastern region. However, the construction of urban rail transit will make cities in central and western regions more attractive to the rural labor force and increase the scale effect of urban economic development. 3) The academic community should carry out research to support the construction of a rail transit policy system and its operation in cities with populations between 1 and 5 million. Seven main types of urban rail transit systems are available, including subway and light rail, and the investment costs of these systems vary greatly. It is important to choose a development system that meets the needs of cities of different sizes, to promote the construction of multi-level rail transit, and to improve and enrich the rail transit structure.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

Authors YZ-l, LZ-h and SC-z were employed by Jinan Rail Transit Group Co., Ltd.

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Publisher's note

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