The heterogeneous impact of China–Europe railway express on the efficiency of logistics industry in node cities

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Abstract

Purpose – The spatiotemporal compression effect of China–Europe Railway Express (CR-Express) can reduce the flow costs of resources between China's node cities. Additionally, it can break through the limitations of low-added-value marine products, significantly impacting the logistics industry efficiency. However, there are few literature verifying and analyzing its heterogeneity. This study explores the impact of CR-Express on the efficiency of logistics industry in node cities and analyzes the heterogeneity.

Design/methodology/approach – First, this study uses panel data to measure the efficiency of node city logistics industry. Secondly, this study discusses the impact of the opening of CR-Express on the efficiency of logistics industry in node cities based on the multi-period differential model. Finally, according to the node city difference, the sample city experimental group is grouped for heterogeneity analysis.

Findings – The results show that CR-Express can promote the urban logistics industry efficiency, with an average effect of 4.55%. According to the urban characteristics classification, the heterogeneity analysis shows that the efficiency improvement effect of logistics industry in inland cities is more obvious. The improvement effect of node cities and central cities in central and western China is stronger, especially in the sample of megacities and type I big cities. Compared with non-value chain industrial products, the CR-Express has significant promotion effects on the logistics efficiency of the cities where main goods are value chain products.

Originality/value – Under the background of double cycle development, this paper can provide a scientific basis for the investment benefit evaluation of CR-Express construction and the follow-up route planning.

Keywords Logistics industry efficiency, China–Europe railway express, Difference-in-difference model, Heterogeneity, Transportation infrastructure

Paper type Research paper

1. Introduction

The development of the urban logistics industry plays a vital role in facilitating "dual circulation". The opening of China–Europe Railway Express (CR Express), an important

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channel for cross-border trade transport, will accelerate the flow of factors between cities and the optimization of resource allocation and drive inland areas to expedite their opening-up efforts and foster international economic and trade cooperation. CR Express brings about a time-space compression effect reducing the logistics costs for node cities engaged in foreign trade. Additionally, the cross-border land transport offered by CR Express improves the current situation characterized by lengthy sea transport, limited involvement from inland areas and low added value. Furthermore, it significantly amplifies the logistics output of node cities by promoting economic and trade cooperation along the CR Express routes (Fang, Lu, & Wei, 2020; Zhou & Zhang, 2021; Li, Min, & Wang, 2021). As of early 2022, 91 cities across China have launched CR Express services. However, several challenges persist, such as disorganized and unplanned operations, competition among node cities for freight sources, as well as high investment, long project cycles and difficulties in measuring the investment benefits of CR Express construction, which arise due to insufficient consideration given to the development of the logistics industry in node cities. Therefore, it is crucial to scientifically select node cities, enhance investment efficiency and effectively promote "dual circulation" by explicitly identifying the impact of CR Express on the efficiency of the logistics industry in node cities.

Currently, most research conducted on the logistics industry in CR Express node cities focuses on assessing and analyzing the current situation. On one hand, some scholars have observed a rapid improvement in the efficiency of the logistics industry in node cities along the "Belt and Road" by calculating its efficiency (Jiang, 2020). On the other hand, research has also demonstrated that improving logistics efficiency can have a substantial impact on promoting bilateral trade flows between regions or countries (Liu & Yin, 2017). However, these findings alone may not sufficiently reflect the differences before and after the opening of CR Express. There is a small amount of literature that specifically focuses on the development of the logistics industry in node cities after the opening of CR Express. Some studies have indicated that the opening of CR Express has significantly facilitated transport convenience for trade between Chongqing and Europe and resulted in a positive impact on the city's development as an international logistics center (Yang, Sun, & Lee, 2020). While there are existing studies on the role of CR Express in improving transport accessibility and promoting domestic and foreign trade circulation (Zhou & Zhang, 2021; Yang *et al.*, 2020), there is a scarcity of literature specifically discussing the impact of CR Express on logistics industry efficiency. By analyzing the logistics transport networks of current node cities, it has been observed that the density of logistics networks in these cities is relatively low. The logistics connections of other node cities mainly rely on intermediary hubs such as Suzhou, Chongqing, Beijing, Nanjing and Wuhan (Wang, Dong, Chen, & Sun, 2018). This finding indirectly suggests that there are shortcomings in the current route planning, including weak connections between node cities, low utilization rates of certain routes and inadequate fulfillment of freight transport demands in certain regions. As a result, it is necessary to further investigation into the subsequent route planning and investment focus for CR Express, providing study opportunities for this paper. Additionally, existing literature demonstrates that the promoting impact of CR Express on the economies of node cities varies depending on their unique characteristics. From a geographical perspective, scholars concur that the opening of CR Express has a more substantial promoting impact on western China (Zhou & Zhang, 2021; Wei & Gu, 2021a). From the standpoint of city type, the economic promotion impact resulting from the opening of CR Express is stronger for larger cities as well as cities with a lower level of economic development (Fang *et al.*, 2020; Zhou & Zhang, 2021; Wei & Gu, 2021b).

From the perspective of the heterogeneity of node cities, this paper, based on panel data collected from 154 prefecture-level cities during the period of 2008 to 2021, adopts a time-varying difference-in-differences (DID) model to investigate the impact of CR

Express on the efficiency of the urban logistics industry. Furthermore, the study also delves into the heterogeneity of node cities. The heterogeneity analysis in this study primarily relies on city-level data. The node cities are categorized based on the main types of goods, differentiating them according to the value level of products. Geographical location is also considered, as it can reveal the unique characteristics resulting from a city's position within the railway network. Additionally, city size is taken into account as a reflection of the economic levels of different cities. Through this categorization, the study aims to analyze the varied effects of CR Express's opening on the efficiency of the logistics industry in different types of cities. An accurate assessment of the impact of CR Express's opening on the efficiency of the urban logistics industry is crucial. This analysis will not only broaden the research on the economic effects of CR Express's opening but also enable the evaluation of the benefits derived from project construction investments, providing a valuable reference for future investment focus and route planning concerning CR Express.

2. Study design

2.1 Assumptions of the basic model

A literature review indicates that changes in the city's internal and external environments (Liu & Yang, 2019; Liu, Li, & Li, 2022; He, Wang, & Xu, 2023) as well as the macroeconomic situation (Wang, Guan, & Dong, 2018) also lead to a higher efficiency of the urban logistics industry. Therefore, this study adopts the DID method to address potential endogenous problems (Thorsten, Ross, & Alexey, 2010). The traditional DID model requires the same time of policy implementation. However, since the opening time of CR Express varies across cities, it does not fit the traditional model. Thus, this study adopts a quasi-natural experiment of CR Express's opening and utilizes a time-varying DID model with fixed time and individual to explore the impact of CR Express's opening on the efficiency of the urban logistics industry. The specific model is set as follows:

$$\theta_{it} = \beta_0 + \beta_1 Treat_i \times Post_t + \beta \sum C_{it} + v_i + v_t + v_{it} \tag{1}$$

where, θ represents the efficiency of the urban logistics industry; β_0 represents the intercept; β_1 represents the difference between policy impacts on the treatment group and the control group after CR Express's opening; i and t represent the prefecture-level city and year respectively; β_1 is significantly positive if the opening of CR Express improves the efficiency of the logistics industry; *Treat* represents the policy dummy variable, which is recorded as 1 if the sample city launches CR Express within the research year, otherwise 0; *Post* represents the time dummy variable, which is recorded as 1 from the opening year of the sample city, otherwise 0; C represents the control variable; v_i and v_t represent individual and time fixed effects respectively; v_{it} represents the disturbance item.

2.2 Measurement of data and variables

This study utilizes a sample of 154 prefecture-level cities, which includes Beijing and municipalities directly under the central government, spanning the period of 2008–2021. The relevant data such as inputs, outputs and control variables of sample cities are obtained from the *China City Statistical Yearbook*, as well as local statistical yearbooks and annual reports. The actual opening time of CR Express for the sample cities (i.e. the policy and time variables) is based on publicly available information. This information is sourced from the Belt and Road Portal (www.yidaiyilu.gov.cn), the *2016–2020 Development Plan of CHINA RAILWAY Express*, development reports of CHINA RAILWAY Express over the years and announcements on government websites. The

opening time of CR Express for the node cities in this study refers to the first opening time of CR Express in these specific cities.

2.2.1 Explained variable: efficiency of the urban logistics industry. Data envelopment analysis (DEA) is primarily used in measuring the efficiency of the urban logistics industry. Its application in the field of logistics has been proven to be feasible (Markovits-Somogyi & Bokor, 2014). Indeed, there has beenmany researches on the application of DEA for measuring the efficiency of the urban logistics industry. Scholars in the field have developed a comprehensive system of models and indicators that are specifically designed to assess the efficiency of the urban logistics industry using DEA (Wang, Dong *et al.*, 2018; Wang and Tan, 2013). Since DEA does not require making any hypothesis about weights, it can avoid measurement errors caused by subjective factors. However, the traditional DEA model can only proportionally reduce in the radial direction and adjust the input and output, failing to measure all slack variables. Consequently, it yields inflated efficiency values and situations where multiple assessment indicators result in a DEA efficiency value of 1 often occur. To address this, this study adopts the super-slacks-based measure-data envelopment analysis (SBM-DEA) model based on relevant literature to measure the efficiency of the urban logistics industry (He *et al.*, 2023; Tone, 2001). Through literature screening, an assessment indicator system for logistics industry efficiency is established. The input indicators include labor input (Jiang, 2020; Liu & Yang, 2019), capital input (Liu, Li, & Li, 2022; Yu & Qian, 2018) and route input (Wang & Tan, 2013; Zhang & Wang, 2018). Specifically, the number of employees in transport, warehousing and postal industries, the fixed asset investment in these industries and the highway mileage are chosen as input indicators. Because the logistics industry is a typical production-oriented service sector, the freight volume is selected to represent its physical output, while the gross product of transport, warehousing and postal industries is chosen to represent its value output.

2.2.2 Explanatory variable: opening of CR express. To capture the direct impact of CR Express on the efficiency of the urban logistics industry, based on the *2016–2020 Development Plan of CHINA RAILWAY Express*, this study defines a set of 38 cities with CR Express operations and direct access to Europe as "node cities", including Chongqing, Zhengzhou, Chengdu, Yiwu (Jinhua), Xi'an and Wuhan, among others. These node cities are considered the treatment group in the analysis, with *Treat* being recorded as 1 from the year of CR Express's opening. In cases where CR Express does not open in a city by the end of a particular year, this study references previous research to record the actual opening time of CR Express (Wei & Gu, 2021b; Liu, Li, & Li, 2022). If the opening occurs in September or earlier, *Post* is recorded as 1 from the current year. Otherwise, it is recorded as 1 from the following year.

2.2.3 Control variable. Based on previous literature (Yu & Qian, 2018; Zhang & Wang, 2018), this study adopts the following control variables: government support environment (Gc), i.e. the proportion of fixed asset investment in the logistics industry compared to the total social fixed asset investment; scientific and technological level (Net), i.e. the proportion of fixed asset investment in the information transmission, software and information technology service industry compared to the total social fixed asset investment; regional industrial structure (In), i.e. the ratio of the tertiary industry to the secondary industry in a city; economic development level (Eco), which is measured by the regional gross domestic product (GDP) per capita; extent of opening-up (Open), which is measured by the proportion of the total import and export volume of a city in its GDP; regional R&D level (Rd), which is measured by the number of granted patents in a city; foreign direct investment (Fdi), i.e. the actual amount of foreign direct investment in a city; urbanization rate (Urb), i.e. the proportion of the urban population in a city. Control variables are all subject to logarithmic value processing. The characteristics of the main variables are shown in Table 1.

Table 1. Main variable characteristics

Variable		Symbol	Observed value	Mean value	Standard deviation	Minimum value	Maximum value
Explained variable	Efficiency of the logistics industry	θ	2156	0.011	0.106	0.00000157	1.865
Environment variable	Government support environment	Gc	2156	0.087	0.055	0.00000533	0.560
	Scientific and technological level	Net	2156	0.012	0.026	0.00000003	0.468
	Foreign direct investment	Fdi	2156	146350.916	424857.722	3.00000000	13211603.214
	Economic development level	Eco	2156	55033.316	36014.498	99.00000000	467749.000
	Regional industrial structure	In	2156	0.998	0.546	0.13869299	5.304
	Extent of opening-up	Open	2156	7.340	328.286	0.00064436	15247.030
	Regional R&D level	Rd	2156	9191.397	20304.633	14.00000000	279509.000

Source(s): Authors' own work

3. Analysis of empirical results

3.1 Baseline regression results and analysis

The baseline estimation results are given in Table 2. Interaction terms and control variables are introduced in sequence. Both the first and second columns control the fixed effects of interaction terms to ensure that individual and time effects of sample cities will not affect the results. The results show the coefficients of *Treat* × *Post* are all significantly positive. The interaction term coefficient of *Treat* × *Post* in Column 2 is 0.0455235, demonstrating that the opening of CR Express improves the efficiency of the logistics industry by 4.55% on average. This indicates that the opening of CR Express is conducive to improving the output and income of the urban logistics industry, thus improving the overall efficiency of the urban logistics industry.

From Table 2's second column that controls the two fixed effects, it is evident that among the control variables, the coefficient of the economic development level (Eco) is positively significant, indicating that cities with higher economic development levels exhibit higher efficiency in their logistics industry. This is because economically developed cities typically possess stronger support for the development of logistics infrastructure. Additionally, they provide logistics supplies that are aligned with the economic and social demands, thus facilitating improvement in urban logistics industry efficiency (Wang & Li, 2019). The coefficient of the regional R&D level (Rd) is positively significant, indicating that cities with higher R&D levels exhibit higher efficiency in their logistics industry. This can be attributed to the fact that cities with higher regional R&D levels tend to have advanced logistics technology and equipment. This, in turn, facilitates the adoption and utilization of advanced logistics technology, driving improvement in the efficiency of the urban logistics industry (Zhou, Chen, & Dan, 2023).

3.2 Robustness tests

3.2.1 Parallel trend test. The DID model relies on a basic hypothesis that, if the policy is not implemented, the efficiency levels of the logistics industry in two groups of sample cities would exhibit a parallel trend. In this study, the test is performed by the event study method (Jacobson & Sullivan, 1993). The specific model is as follows.

Variable	Interaction item introduced	Control variable introduced
Treat×Post	0.042* (0.023)	0.045524** (0.022111)
Gc	–	0.001340 (0.001055)
Net	–	0.015278 (0.020176)
Fdi	–	−0.058276 (0.042854)
Eco	–	0.259537* (0.1567230)
In	–	−0.254980 (0.170765)
Open	–	−0.025189 (0.057531)
Rd	–	0.000009* (0.000005)
Urb	–	0.000618 (0.002990)
Cons	−7.671*** (0.098)	−9.80571*** (0.596976)
City fixed effect	Y	Y
Year fixed effect	Y	Y
N	2156	2156
R^2	0.401	0.659

Note(s): The number in the parentheses indicates the standard error (clustered to the city level); N represents the number of data entries; R^2 represents the goodness of fit; ***, ** and * represent significance at levels of 1, 5 and 10% respectively

Source(s): Authors' own work

Table 2. Baseline regression result

$$\theta_{it} = \gamma_0 + \sum_{w\geq -5}^{5} \gamma_w D_{it}^{w} + \gamma \sum C_{it} + v_i + v_t + v_{it} \quad (2)$$

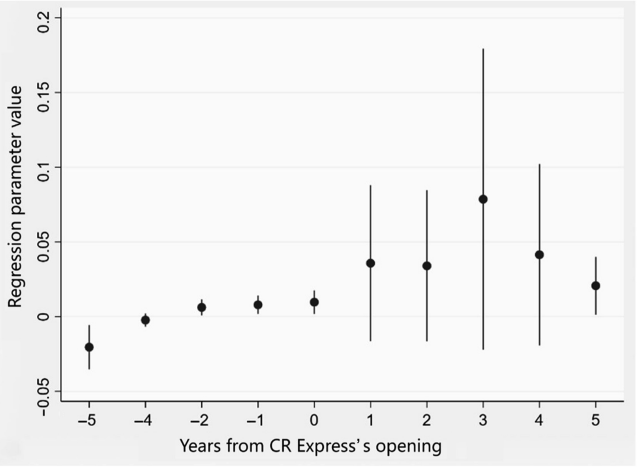
where: θ represents the efficiency of the urban logistics industry; D_{it}^{w} represents the dummy variable for the CR Express opening year; if w is less than 0, it indicates that this period is the year w before CR Express's opening and if w is greater than 0, it indicates that this period is the w year after CR Express's opening; γ_w represents the direction of impact of CR Express's opening on the efficiency of the urban logistics industry; C represents the control variable; v_i and v_t represent individual and time fixed effects respectively; v_{it} represents the disturbance term.

The initial year is defined as the current year when CR Express opens and 5 years before and after it is also considered. If w is less than 0 and γ_w is not significantly different from 0, it passes the parallel trend test. Figure 1 illustrates the parallel trend test on the impact of CR Express's opening on the urban logistics industry efficiency. According to Figure 1, before CR Express's opening, γ_w cannot reject the null hypothesis and pass the parallel trend test. Further analysis of the dynamic trend shows that after the initial year, γ_w exhibits an obvious positive trend which is relatively stable. This reveals that the opening of CR Express exerts a long-term effect on the efficiency of the urban logistics industry.

3.2.2 Placebo test. Another basic hypothesis of the DID model is that it is affected by unobservable factors. To exclude the impact of other unobservable missed variables, a placebo test is conducted following the empirical practice of previous studies (Li, Lu, & Wang, 2016). The placebo test involves randomly generating node cities. To be more specific, 1000 and 2000 trials are conducted on the efficiency of the urban logistics industry respectively according to the second column of Table 1. The regression coefficient $\widehat{\beta}_1$ is expressed as follows:

$$\widehat{\beta}_1 = \beta_1 + \mu \times \frac{\mathrm{cov}(Treat_i \times Post_t, \varepsilon_{it}|C)}{vzr(Treat_i \times Post_t|C)} \quad (3)$$

where, $\widehat{\beta}_1$ represents the coefficient estimated value; μ represents the impact of unknown factors and C represents the control variable. In the trials, the list of cities that have launched



Source(s): Authors own work

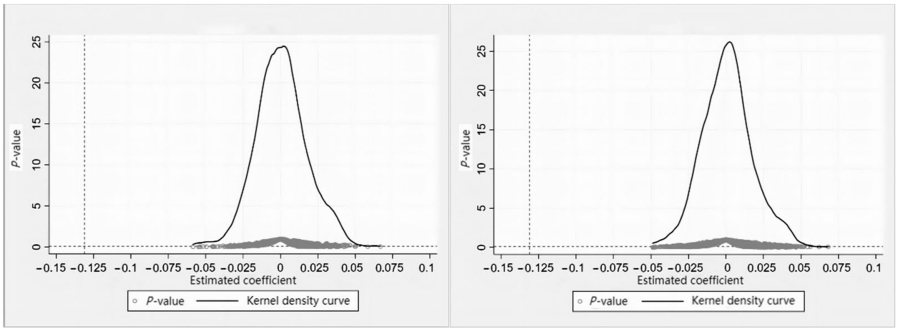
Figure 1.
Parallel trend test

CR Express, i.e. the actual policy effect $\beta_1 = 0$, is randomly generated. If $\widehat{\beta}_1$ is not 0, this indicates that the results of this study may be affected by unobservable factors. The left panel and right panel in Figure 2 illustrate the distribution of P-values upon 1000 and 2000 trials on $\widehat{\beta}_1$ respectively. Wherein, the X-axis shows the coefficient estimated values of $\widehat{\beta}_1$ and the Y-axis shows the probability density values and P-values; the vertical dotted line shows the true estimated values of the DID model and the horizontal dotted line shows the significance level of 0.1; the black dots show the corresponding P-value of $\widehat{\beta}_1$ and the curve shows the kernel density distribution of the estimated coefficients.

It can be seen from Figure 2 that most of the estimated coefficients concentrate around zero and their P-values are greater than 0.1 (not significant at the level of 10%). This demonstrates that the baseline regression results of this study are not accidental, so the probability of the study results being affected by other policies or random factors is extremely low. It proves that the impact of CR Express's opening on the efficiency of the urban logistics industry is not affected by other factors. Namely, the impact of CR Express's opening is robust in improving the efficiency of the urban logistics industry.

3.2.3 PSM-DID test. This study re-examines the impact of CR Express's opening on the efficiency of the logistics industry based on the propensity score matching-differences-in-differences (PSM-DID) analysis. The purpose is to alleviate the endogenous and selective errors in the study and reduce the difference between the treatment group and the control group before the opening of CR Express (Heyman, Sjoholm, & Tingvall, 2007). This study adopts the 1:4 nearest neighbor matching with replacement, radius matching and kernel matching. According to the list of node cities obtained after matching, the DID model is used again. The test results in Table 3 show that the coefficient $Treat \times Post$ is positively significant and the results are similar to those of baseline regression, demonstrating that the conclusions of this study are robust.

3.2.4 Other robustness tests. In addition to the robustness tests described above, other robustness tests are also adopted. (1) Node cities of CR Express are selected from areas along the Belt and Road. This is an endogenous trouble. According to the practice of previous studies (Li *et al.*, 2021; Wei & Gu, 2021b), the two-stage regression method is used to test the cities along the ancient "Silk Road" (Pcity) as an instrumental variable. The test results are given in the first and second columns of Table 4. The conclusions of this study are robust; (2) To account for the potential "pseudo regression" between the efficiency of the urban logistics industry and the opening of CR Express, the tests are conducted by shifting CR Express's



1000 Trials
(a)

2000 Trials
(b)

Source(s): Authors own work

Figure 2.
Placebo test

opening year *Post* in all node cities forward by one year and two years (*Post*01; *Post*02). The results are given in the third and fourth columns of Table 4. It is observed that the interaction term coefficient is not significant, proving that there is indeed a correlation between them; (3) Measuring the efficiency of the logistics industry by super-SBM-DEA may have an impact on the regression results. Moreover, the value output of the urban logistics industry, a typical production-oriented service sector, is usually expressed by the gross product of the logistics industry (Liu, Li, & Li, 2022). Therefore, based on the practice of Li Jia *et al.* (Li *et al.*, 2021), the gross product of the logistics industry is used as the proxy variable for testing the efficiency of the urban logistics industry. The results are given in the fifth column of Table 4. The interaction term coefficient remains significant, demonstrating that the conclusions of this study are robust; (4) In view that the sample data are affected by outliers, the variable of the efficiency of the logistics industry and the control variables of sample cities are winsorized at 1% and 5% respectively. Then, a re-empirical analysis is conducted. The results are given in the sixth and seventh columns of Table 4, again demonstrating that the conclusions of this study are robust.

4. Heterogeneity analysis

To explore the heterogeneity in the impact on improving logistics industry efficiency related to the characteristics of node cities, these cities are grouped based on the type of goods, geographical location and city size. The categorization of the sample cities is presented in Schedule 1 in the annex.

4.1 Heterogeneity in improving the efficiency of the logistics industry in cities with different types of goods

The "point-to-point" through mode of CR Express is characterized by its timeliness, safety and regional accessibility. This mode of transport significantly reduces transport costs, which is particularly beneficial for value chain industries with high demands for efficient distribution (Liu, Li, & Li, 2022). According to the 2019 report "Globalization in transition: The future of trade and value chains" by McKinsey Global Institute, six industries are identified as value chain industries. These industries include chemical engineering, automotive, computers and electronics, machinery and equipment, electrical machinery and transport equipment. In this study, tests are conducted on the variable of products of value chain industries. If a city's main export products come from these specific industries, the corresponding value for this variable is set to 1. Otherwise, the variable value is set to 0. The results are given in Table 5. The interaction term coefficients of products of value chain industries and core explanatory variables are found to be significantly positive. On the other hand, the coefficient of products of non-value chain industries is not significant. This

Matching method	Nearest neighbor matching	Radius matching	Kernel matching
Treat×Post	0.058** (0.028)	0.162** (0.069)	0.047** (0.017)
Control variable	Y	Y	Y
City fixed effect	Y	Y	Y
Year fixed effect	Y	Y	Y
N	667	2078	1549
R^2	0.824	0.634	0.554

Source(s): Authors' own work

Table 3. Estimated result of PSM-DID

Table 4.
Other robustness tests

Test method	Instrumental variable method		Shifting the opening year forward		Conversion measurement method	Excluding outliers	
Breakdown	Stage 1	Stage 2	One year forward	Two years forward	Gross product of the logistics industry	Winsorized at 1%	Winsorized at 5%
Treat×Post	–	0.136*	–	–	974089.500***	0.009** (0.004)	0.053* (0.032)
Pcity×Post	0.207***	–	–	–	–	–	–
Treat×Post01	–	–	0.114 (0.061)	–	–	–	–
Treat×Post02	–	–	–	0.113 (0.061)	–	–	–
Control variable	Y	Y	Y	Y	Y	Y	Y
City fixed effect	Y	Y	Y	Y	Y	Y	Y
Year fixed effect	Y	Y	Y	Y	Y	Y	Y
N	2156	2156	2156	2156	2156	2156	2156
R^2	0.228	0.477	0.585	0.145	0.576	0.559	0.585
F–stat	990.350	–	–	–	–	–	–

Source(s): Authors' own work

Type of goods	Products of value chain industries	Products of non-value chain industries
Treat×Post	0.164** (0.067)	0.057 (0.040)
Control variable	Y	Y
City fixed effect	Y	Y
Year fixed effect	Y	Y
Number of treatment group cities	29	9
N	2030	1750
R^2	0.685	0.707

Source(s): Authors' own work

Table 5. Heterogeneity of goods type

suggests that CR Express has a significant impact on improving the efficiency of the logistics industry in cities where the main goods belong to value chain industries. This may be attributed to the fact that most of the goods transported by CR Express trains are chemical products and mechanical equipment and China and European countries cooperate more closely in the value chain of these industries (Liu, Li, & Li, 2022). This finding also proves that the opening of CR Express provides an important opportunity for China's urban logistics industry to participate in the division of labor in the global value chain, which is conducive to promoting China's position in the global value chain.

4.2 Heterogeneity in improving efficiency of the logistics industry in cities at different geographical locations

In this study, sample cities in the treatment group are divided into eastern, central, western and northeastern sub-samples as well as coastal and inland sub-samples based on their locations and coastal status. The division of these cities is determined by the locations of their provinces/municipalities. The comprehensive calculation results are given in Table 6. The opening of CR Express has a positive effect on improving the efficiency of the logistics industry in eastern, central, western, northeastern and inland regions while the impact on coastal cities is not significant. Moreover, the interaction term coefficients of sub-samples in central, western and inland regions are greater, proving that the opening of CR Express has a stronger effect on improving the efficiency of the logistics industry in node cities in central, western and inland regions. This also indicates that the opening of CR Express has brought new opportunities for the logistics industry development in these regions. It is conducive to minimizing the imbalance in the logistics industry development between various regions and narrowing the development gap between the central and western regions and the eastern coastal region of China, thus promoting the common improvement of the logistics industry development in cities at different locations. The impact of CR Express on improving the efficiency of the logistics industry in northeastern China is relatively weak. This can be attributed to the relatively weak high-tech industrial foundation of cities in the northeastern region (Wei & Gu, 2021b). During the study years, the main export products of these cities are low value-added goods. Additionally, the operations of CR Express in this region are insufficient to meet the demand for goods transport (Liu, Li, & Li, 2022). Similarly, the opening of CR Express does not yield a significant improvement in the efficiency of the logistics industry in coastal cities. This is because the logistics industry in coastal cities predominantly relies on water transport. As a result, the impact of CR Express on the logistics industry in these cities is insufficient.

Additionally, according to the "center-periphery" theory (Prebisch, 1962), it is easier for regional central cities to reduce factor transport costs and strengthen the trend of factor

Table 6.
Geographical location heterogeneity

Classification criteria	City location				Coastal/Inland		Central/Peripheral	
Sub-sample	Eastern China	Central China	Western China	Northeastern China	Coastal area	Inland	Central city	Peripheral city
Treat×Post	0.051* (0.039)	0.347* (0.223)	0.116* (0.074)	0.005* (0.094)	0.021 (0.020)	0.159** (0.077)	0.107* (0.058)	0.030* (0.017)
Control variable	Y	Y	Y	Y	Y	Y	Y	Y
City fixed effect	Y	Y	Y	Y	Y	Y	Y	Y
Year fixed effect	Y	Y	Y	Y	Y	Y	Y	Y
N	1890	1722	1750	1666	1791	1988	1736	2044
R^2	0.527	0.854	0.844	0.845	0.835	0.898	0.838	0.629

Source(s): Authors' own work

resource inflow (Li *et al.*, 2021). Therefore, they certainly have more advantages than peripheral cities. Many central cities are also node cities and their industrial concentration effect and scale economy effect are stronger than peripheral cities. Therefore, the impact of CR Express's opening on their logistics industry efficiency should be different. According to the construction plan issued by the National Development and Reform Commission, 8 CR Express hubs are classified as central cities, including Urumqi, Chengdu, Zhengzhou, Chongqing, Shenyang, Xi'an, Jinan and Hefei. Other node cities are classified as peripheral cities. Empirical analysis is conducted on the two city groups and the results are shown in Table 6. The interaction term coefficients of central cities and peripheral cities are all positively significant. However, the interaction term coefficients of central cities are greater, demonstrating that CR Express's opening has a greater impact on the efficiency of the logistics industry in central cities compared to peripheral cities.

4.3 Heterogeneity in improving efficiency of the logistics industry in cities of different sizes

Considering that the different economic development levels of different cities due to city size have a great impact on the promotion role of CR Express, this study analyzes the heterogeneity from the aspect of city size. According to the latest classification criteria specified in the *Tabulation on the 2020 China Population Census by County*, empirical study is conducted on node city groups, i.e. super-large cities, megacities, Type-I large cities, Type-II large cities and small and medium-sized cities. As shown in Table 7, the opening of CR Express improves the efficiency of the logistics industry in cities of different sizes. The coefficients of interaction term *Treat* × *Post* of megacities and Typ-I large cities are greater, indicating that the opening of CR Express has a stronger role in improving the efficiency of the logistics industry in these cities compared to other cities. This is because super-large cities such as Guangzhou and Shenzhen have a higher level of economic development, but the effect on import and export growth is low in regions with a higher level of economic development (Zhou & Zhang, 2021). Furthermore, all super-large cities except Chongqing are located in eastern China and CR Express has a weaker effect on improving the efficiency of the logistics industry in eastern China. The opening of CR Express has a weaker improvement role in Type II large cities and small and medium-sized cities because most of the samples of these cities are located in the coastal area. Coastal cities account for 3/10 of samples of Typ-II large cities and 1/3 of samples of small and medium-sized cities. However, coastal cities only account for 3/11 of samples of megacities and 1/6 of samples of Type-I large cities. This can also be proved by the fact that CR Express has no significant effect on improving the efficiency of the logistics industry in coastal cities.

City size	Super-large cities	Megacities	Type I large cities	Type II large cities	Small and medium-sized cities
Treat×Post	0.0706739*	0.1010606**	0.2454778***	0.014689*	0.0907041*
	(0.14436)	(0.05212)	(0.06750)	(0.00559)	(0.05863)
Control variable	Y	Y	Y	Y	Y
City fixed effect	Y	Y	Y	Y	Y
Year fixed effect	Y	Y	Y	Y	Y
Number of treatment group cities	5	11	6	10	6
N	1694	1778	1708	1764	1708
R^2	0.739	0.755	0.628	0.655	0.556

Source(s): Authors' own work

Table 7. Urban size heterogeneity

5. Conclusions and implications

Through the quasi-natural experiment of CR Express's opening, this study establishes a time-varying DID model based on panel data from 154 prefecture-level cities in 2008–2021 to explore the effect of CR Express's opening on the efficiency of the urban logistics industry. Furthermore, the parallel trend test, placebo test and PSM-DID regression are performed to test the robustness of this model. The empirical results indicate: (1) The opening of CR Express leads to a 4.55% improvement in the efficiency of the urban logistics industry on average; (2) The impact of CR Express on logistics industry efficiency is significantly greater in cities where the main goods are products of value chain industries when compared to cities where the main goods are products of non-value chain industries; (3) The improvement effect on logistics industry efficiency is more pronounced in central, western and inland regions, as well as in central cities, particularly megacities and Type-I large cities. Based on these conclusions, the following recommendations are proposed.

(1) Actively expand the types and channels of goods for CR Express in node cities to enable products of value chain industries to dominate the goods transported. CR Express trains can be utilized for the cross-border transport of products of value chain industries to be exported near node cities. In contrast, products of non-value chain industries in node cities can be transported by other means or concentrated at nearby CR Express hubs for transport.

(2) The operations of CR Express are primarily influenced by factors such as freight demand and government support. Moreover, cities in central and western China offer substantial subsidies to attract freight sources. As a result, CR Express operations can be increased in the plans for central cities in central and western China, especially megacities and I-type large cities. Meticulous investigations should be conducted for future construction of CR Express in the eastern and coastal regions, thus avoiding resource waste. For small and medium-sized cities with a significant demand for export freight, such as Yiwu, it is advisable to further increase CR Express operations. Additionally, comprehensive considerations should be given to enhancing the utilization rate of CR Express in coastal cities, leveraging its potential to catalyze the development of the logistics industry in these cities. Furthermore, northeastern China should accelerate its industrial upgrading process and focus on developing high-tech industries to increase the added value of products.

This study validates the role of CR Express in improving the efficiency of the logistics industry in node cities and performs heterogeneity analysis. However, due to the difficulty in obtaining railway freight data classified by the type of goods in node cities, it was not possible to conduct further examinations regarding the impacts of factors such as railway freight volume, types of goods, location characteristics and planning of railway logistics bases. We will incorporate such impacts in future studies to further consolidate the understanding of the role of CR Express in improving the efficiency of the logistics industry in node cities.

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