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Analysis on shock effect of China's high-speed railway on aviation transport

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ABSTRACT

As China's high-speed railway featured by low-carbon quick prospers rapidly, railway transport has been regarded as a crucial means to replace the aviation transport. Selecting the data from 156 routes of China's 48 major cities from 2001 to 2014, the paper takes the aviation mileage as the threshold variable and the operation time as the control variable to build a panel threshold regression model. Firstly, under the consideration of the economic, demographic, environmental and railway indicators, the paper analyzes the influence of China's railway on the aviation passenger volume and the flight number; secondly, under the condition that the railway speed is more than 250 km/h, the paper analyzes the shock effect of China's high-speed railway on aviation transport. The conclusion shows that the higher the level of the economic development is, the more developed the aviation transport of the region will be. when the aviation mileage is below 1132 km, as the aviation mileage increases, the influence of China's railway to the aviation transport fall into a decline; China's high-speed railway has a positive shock effect on the aviation transport, and the shock effect reaches the maximum when the aviation mileage is from 650 to 755 km. This paper is of great practical significance to study the optimization of transportation structure.

1. Introduction

Since China's first high-speed railway passenger transport line, Beijing-Tianjin Intercity High-Speed Railway thoroughly opened in August 2008, Wuhan-Guangzhou (December 2009), Zhengzhou-Xi 'an (February 2010), Shanghai-Nanning (July 2010), Shanghai-Hangzhou (October 2010), Beijing-Shanghai (June 2011) and other high-speed railways were successively put into use, leading to a dramatic increase of the mileage of China's high-speed railway. By the end of 2014, total operating mileage of high-speed railways in China had accumulated to 16,727 km, which was far more than that of any other country. By the end of 2015, the operating mileage of high-speed railways in mainland China reaches 19,915 km. The railway passenger volume in China also increased from 1085.79 million in 1986 to 2530 million in 2015, with an increase of 133.01%. Functionally speaking, the aviation transport and high-speed railway transport are all relating to transport passengers form one place to another place, to serve the passengers' needs well. They are substitutable to a certain extent. With the characteristics of comfort, rapidness, convenience and punctuality rate, the high-speed

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railway has put a powerful influence on the aviation industry (Óscar et al., 2015; Marie and Frédéric, 2015; Daniel and Xavier, 2016; Mu et al., 2015; Chen and Haynes, 2015). Since Beijing-Shanghai High-speed Railway opened in 2010, the airline passenger volume from Beijing to Shanghai has dropped by 9.9%, from 7,473,355 in 2010 to 6,730,218 in 2013. Since Beijing-Guangzhou High-speed Railway opened in 2012, the airline passenger volume from Beijing to Wuhan has dropped by 23.8%, from 1,747,549 in 2013 to 1,330,864 in 2014. The airline passenger volume from Harbin to Shenyang has dropped by 70.9%, from 329,822 in 2010 to 95,856 in 2012. Therefore, the analysis on the shock effect of China's high-speed railway on aviation transport in China has become such an immediate task for us.

As for the study of high-speed railway and aviation transport, at present, the scholars at home and abroad studied the influence of high-speed railway to aviation transport, from the angle of demands of the high-speed railway (Maria, 2014), the influence of the high-speed railway to regional economy (Hyojin and Selima, 2015; Roger, 2015; Shailesh and Sharada, 2014; Guineng and João, 2014; Wang et al., 2012), the service cost of the aviation industry (Frédéric et al., 2014; Yang and Zhang, 2012), the shock to the traveling time brought by the high-speed railway (Kamga, 2015; Mu et al., 2015; Zhao et al., 2015; Daniel and Xavier, 2016), and the competition with high-speed railway from the different air routes (Jiang and Zhang, 2014; Óscar et al., 2015; Marie and Frédéric, 2015; Daniel and Xavier, 2016; Wu et al., 2014; Chen and Haynes, 2015). In which the shock from adjusting the railway network is the most obvious. By using the data from 1995 to 2009, Clewlow et al. (2014) analyzed the influences of the high-speed railway and budget airline to the demand of air travel at three different levels: air routes, traveling within the country and traveling in the selected European area. By taking GDP, population, population density, aviation fuel price, change of the time consumed by the railway, high-speed railway and the routes of budget airline as the variables, he used ordinary regression and panel regression to analyze the influences of the high-speed railway and budget airline to the demand of air travel. The results showed that population and population density had a significant influence in different levels, but under the condition of excursions, the influence of population density was negative, which meant that the higher the population density was, the more attention people would pay to the railway when going on an excursion. For the trips taking within the country or excursion, the high-speed railway had a larger impact on aviation, but the increase of long trips and budget airlines promoted the total demand of traveling by air. Based on the aviation data from four European countries France, Germany, Italy and Spain, Albalate et al. (2015) studied the competition and cooperation between the high-speed railway and aviation transport. Taking the flight number and the aviation passenger volume as dependent variable, and GDP, population, distance, time, market share, low-cost airline, central airport and so on as the independent variable, he built a regression mode, whose conclusion was that the shock from the high-speed railway to the aviation was not large, and the shock mainly existed in the central airport where high-speed railways were also available.

Studies have shown that the high-speed railway has certain effect on economy, trade, tourism and aviation industry. Due to the substitutability between the means of transportation, the influence from the high-speed railway to aviation industry is more obvious. The current researches relating to the shock effect of high-speed railway on the aviation transport are mainly made from analyzing the relationship between the railway passenger volume, time consumed by the railway and GDP, population, flight number and airline passenger volume. The paper introduced the aviation mileage, an important factor to both railway and aviation, to analyze the impact of railway on aviation, and tried to make an analysis of the impact brought by the environmental pollution. Because the general metrological model can only analyze the linear regression model, it is helpful to analyze the segment effect of the railway mileage on the aviation mileage by using the panel threshold regression model. Considering of the aviation substitution effect brought by the opening of the high-speed railway in China, the paper regarded the distance between two places as an important factor influencing what the consumer would choose between the high-speed railway and the aviation transport when taking a trip. Meanwhile, considering that the aviation had a large impact on the environment, the paper added the discharge amount of pollutants at both departure and destination to the threshold regression model as a factor influencing the environmental pollution. Besides, the influence of the whole railway network was also taken into consideration in the paper. Based on the aviation mileage a panel threshold progression model was established to describe the segmentation effect of the impact of railway and high-speed railway on aviation.

The structure of this paper is as follows. The first part is the introduction, introducing the background of the paper and reviewing the existing research on the impact of the high-speed railway on the aviation. The second part is an introduction of the threshold progression model. The third part is the empirical analysis, including (1) indicator selection and data preprocess; (2) the shock effect of China's railway on aviation transport; (3) the shock effect of China's high-speed railway on aviation transport industry. (4) The fourth part is the conclusions.

2. Introduction of threshold autoregressive model

Since Tong (1983) put forward the transformation theory of mechanisms, threshold regression model began to sprout. As the econometrics develops, Bai and Perron (1998) introduced the test and estimation of multivariate linear model of structure change, while Hansen (1996) put forward the test and estimation of the threshold autoregressive model for a time series data. So far, the threshold regression model has been widely used in the field of economic research. With the development of the theory, the panel data is introduced into the threshold regression model. Hansen (1999, 2000) introduced an econometric analysis methods of individual fixed-effect static panel data threshold regression model. He eliminated the individual fixed effect by removing mean within the group, estimated by using OLS, and tested the significance of the threshold effect through bootstrap calculation method. Since the endogenous explanatory variable was not included in Hansen (1999)'s study, Donald et al. (2004) used the simplified model to process the endogenous explanatory variables and put forward a panel threshold model with endogenous explanatory variables and one exogenous threshold variable. Kremer et al. (2013) used the forward orthogonal deviation method to eliminate the individual effect, to avoid the residual items after the transformation process had serial correlation. He applied the distribution theory of static panel threshold model to the dynamic panel threshold model. To analyze the direct shock of China's railway transport to aviation transport industry, the paper selects the operation time of the railway as a reflection of the operation at the departure and the destination, to be the control variable of the regression model and builds a panel threshold regression model containing endogenous variables. According to Donald et al. (2004)'s study, the paper takes the aviation mileage as the threshold variable, to build the panel regression models with one, two and three thresholds of China's railway on aviation transport.

(I) Panel regression model with one threshold

$$y_{kit} = c_{ki} + \alpha_k^{\theta} x_{kit}^{\theta} + \beta_k^0 railtime_{kit} + e_{kit},\ miles_{it} \leqslant \gamma \tag{1}$$

$$y_{kit} = c_{ki} + \alpha_k^{\theta} x_{kit}^{\theta} + \beta_k^1 railtime_{kit} + e_{kit},\ miles_{it} > \gamma \tag{2}$$

where $k \in \{1, 2\}$ represents number of the dependent variables, $y_{kit} = [passenger_{it}, frequency_{it}]$, passenger represents the passenger volume at the departure and the destination, frequency represents the flight number at the departure and the destination, i represents the number of airlines at the departure and the destination, and t represents time. The paper takes the passenger volume and frequency at the departure and the destination as dependent variables to build model 1 and model 2 respectively, to analyze the influence of the economy, population, environment and railway on the aviation industry. x_{it}^{θ}, $\theta \in \{1,2...6\}$ are the independent variables, representing respectively gross domestic product (GDP), population at the departure and the destination (population), the discharge amount of pollutants at both departure and destination (pollution), whether the railway routes at the departure and the destination are the main railway lines (artery is a dummy variable), whether the railway speed is the high-speed (high-speed is a dummy variable). The control variable is the operation time of the railway network (railtime); "the threshold variable" is the aviation mileage (miles); γ represents the threshold value, α and β represent coefficients and e represents error term.

Using a dummy variable $I(.)$ to represent indicator function, the model (1), (2) can be rewritten as a form of a single equation:

$$y_{kit} = c_{ki} + \alpha_k^{\theta} x_{kit}^{\theta} + \beta_k^0 railtime_{kit} I(miles_{it} \leqslant \gamma_1) + \beta_k^1 railtime_{kit} I(miles_{it} > \gamma_1) + e_{kit} \tag{3}$$

By adding dummy variables, Eq. (3) can be further rewritten into a matrix form:

$$Y = X_{\gamma_1}\beta + e \tag{4}$$

The corresponding function of residual sum of squares is obtained from the model (4), $S_0 = e'e$ $S_1(\gamma) = e(\gamma_1)'e(\gamma_1) = Y'(I{-}X'_{\gamma_1}(X'_{\gamma_1}X_{\gamma_1})^{-1}X'_{\gamma_1})Y$, I is the unit vector, and the threshold value is estimated by the least square method. When $S_1(\gamma)$ is the smallest threshold value $\hat{\gamma}$ ($\hat{\gamma}_1 = \mathrm{argmin}_{\gamma_1} S_1(\gamma_1)$), e, this value is the threshold value of the final solution. At the same time, construct F statistic:

$$F_1 = \frac{n(T{-}1)(S_0{-}S_1(\hat{\gamma}_1))}{S_1(\hat{\gamma}_1)}$$

where n is the number of airline, and T is the length of time for the study, which are used to judge the significance of the threshold effect. The asymptotic distribution of F statistic is obtained by using the bootstrap method proposed by Hansen, to judge whether the threshold effect exists.

(II) Panel regression model with two thresholds

$$y_{kit} = c_{ki} + \alpha_k^{\theta} x_{kit}^{\theta} + \beta_k^0 railtime_{kit} I(miles_{it} \leqslant \gamma_1) + \beta_k^1 railtime_{it} I(\gamma_1 < miles_{it} \leqslant \gamma_2) + \beta_k^2 railtime_{kit} I(miles_{it} > \gamma_2) + e_{kit} \tag{5}$$

where γ_1, γ_2 represent the estimates of the two thresholds. At the same time, construct F statistic: $F_2 = \frac{n(T-1)(S_1 - S_2(\hat{\gamma}_2))}{S_2(\hat{\gamma}_2)}$ to judge the significance of the threshold effect. Once the panel regression model with one threshold is rejected, we need to judge whether the panel regression model with two or three thresholds exists.

(III) Panel regression model with three thresholds

$$y_{kit} = c_{ki} + \alpha_k^{\theta} x_{kit}^{\theta} + \beta_k^0 railtime_{kit} I(miles_{it} \leqslant \gamma_1) + \beta_k^1 railtime_{it} I(\gamma_1 < miles_{it} \leqslant \gamma_2) + \beta_k^2 railtime_{it} I(\gamma_2 < miles_{it} \leqslant \gamma_3) + \beta_k^3 railtime_{it} I(miles_{it} > \gamma_3) + e_{kit} \tag{6}$$

where γ_1, γ_2, γ_3 represent the estimates of the three thresholds. At the same time, construct F statistic: $F_3 = \frac{n(T-1)(S_2 - S_3(\hat{\gamma}_3))}{S_3(\hat{\gamma}_3)}$ to judge the significance of the threshold effect. Once the panel regression model with one threshold is rejected, we need to judge whether the panel regression model with three thresholds exists.

3. Empirical analysis

3.1. Indicator selection and data preprocess

On the one hand, as the transport industry in China grows rapidly, (Clewlow et al., 2014) the establishment of the network of railway and high-speed railway is bound to have an impact on transport. On the other hand, (Albalate et al., 2015) economy, population and environment will also exert influence on aviation industry. The paper divides the indicators into railway, economy, environment and population four categories to analyze the impact of railway on aviation industry.

(1) *Aviation indicator*. The development of the aviation industry is mainly affected by its bearing capacity, the roundtrips between the departure and the destination, the aviation distance between the departure and the destination. Therefore, the paper chooses airline passenger volume, flight number to measure the level of the aviation industry in China, and the aviation mileage to measure the aviation distance. The data of the airline passenger volume and flight number is from the wind database. The data of the aviation mileage is from the official website of the China Southern Airlines (http://skypearl.csair.com/skypearl/cn/toExchangeStandard.action).
(2) *Railway indicator*. That the construction of the high-speed railway in China is speeding up "makes China smaller". The speed of the high-speed railway has a direct influence on the operation efficiency of the transport. The paper chooses the railway operation time at the departure and the destination, the railway operation speed, and whether there is a high-speed railway at the departure and the destination as indicators to describe the situation of the railway. Moreover, "four vertical and four horizontal" net of expressing passenger is proposed in the "12th five-year plan". The investment of the funds and the operation capacity of the railway are mainly reflected in the main lines of the railway. Based on the "four vertical and four horizontal" net of expressing passenger, define whether it belongs to the network of the high-speed railway in China as a dummy variable. The data of the network of main railway lines is from *the Medium and Long-term Railway Network Planning (Adjustment in 2008)*. The data of the railway operation speed is from the schedule of the sixth "speed boost" of Chinese railways made by the Ministry of Railways. The indicator that whether there is a high-speed railway at the departure and the destination depends on the establishment of China's high-speed railway. The data of the operation time of the railway in 2014 is from the official website of the Ministry of Railways for train tickets (http://www.12,306.cn/mormhweb/), and the data of other years is deduced from the distance between the departure and the destination and the operation speed.
(3) *Economic indicator*. As the economy prospers, the consumption level will be rising accordingly, and it will also directly affect how people choose between aviation and railway for traveling. Therefore, the paper selects the mean of the GDP at the departure and the destination of the routes as an indicator to measure the economy of the region. The data is from the flush iFind database.
(4) *Environmental indicator*. Air quality directly affects the flight safety and affects even more the selection of the aviation made by the passengers. The paper chooses the discharge amount of pollutants as the quality standard of the air. The data is from the wind database.
(5) *Demographic indicator*. The larger the population is, the more influence it will exert on the change of passenger volume, and it will also influence the passenger volume of railway and aviation. Therefore, the paper selects the mean of the population at the departure and the destination of the routes as an indicator to measure the change of the passenger volume. The data is from the flush iFind database.

Aviation indicator, railway indicator, economic indicator, environmental indicator and demographic indicator are all selected from 156 aviation lines from 2001 to 2014, with a total of 2184 samples. As there is no direct and indirect railway line from Xishuangbanna to Lijiang, we select the operation time and the operation speed of high-speed railway as approximate values.

Table 1 shows the descriptive statistics of variables. As can be seen from Table 1, since the unit of the demographic indicator is ten thousand, the unit of the railway operation time is hour, the difference between the mean and the standard deviation is quite large. Therefore, the paper makes logarithmic treatment to the indicators of the aviation passenger volume, the aviation flight number, the aviation mileage, the mean of the economic aggregates at the departure and the destination, the mean of the aggregate population at the departure and the destination, the mean of the discharge amount of the pollutants at the departure and the destination, the railway operation speed and the railway operation time at the departure and the destination, to reduce the absolute value of the data.

Table 1
Descriptive statistics of variables.

Variables	N	Mean	Std. Dev.	Min	Max	Skew	Kur
Lines	2184	78.50	45.04	1	156	0.00	−1.20
Years	2184	2007.50	4.03	2001	2014	0.00	−1.21
Passenger	2184	632524.52	670435.07	51,959	7,473,355	4.20	28.53
Frequency	2184	5336.72	4468.16	566	36,169	2.58	10.54
Miles	2184	1045.72	544.77	314	3326	1.68	4.25
GDP	2184	5035.94	3744.75	31.43	22449.26	1.07	0.81
Population	2184	820.46	441.58	77.90	2708.54	1.06	0.92
Pollution	2184	3796.54	5076.15	183.5	50,661	6.54	52.23
Artery	2184	0.57	0.49	0	1	−0.29	−1.92
Speed	2184	196.16	39.08	90	350	1.48	3.02
Railtime	2184	19.58	11.41	2.83	60.79	0.89	0.34
High-speed	2184	0.10	0.31	0	1	2.59	4.71

Table 2
The estimation results of panel regression.

Variable	Model 1 Fixed effects	Model 1 Random effects	Model 2 Fixed effects	Model 2 Random effects
C	5.632***	6.534***	3.740***	4.341***
Ln *GDP*	0.738***	0.735***	0.712***	0.690***
Ln *population*	−0.011	−0.089	−0.192**	−0.165**
Ln *pollution*	0.031	0.045*	0.002	0.024
artery	0.035	−0.256***	0.005	−0.159
Ln *speed*	0.281*	0.240**	0.008	−0.078
highspeed	−0.271***	−0.272***	−0.092***	−0.114***
Ln *railtime*	−0.118**	−0.151***	−0.024	−0.104***
Hausman test		31.905		39.038
Cross-section chi-square 5	3886.542		3941.735	

Notes: ***, **, * represent significant at 1% level, 5% level and 10% level respectively.

3.2. The shock effect of China's railway on the aviation transport industry

3.2.1. Results of the panel regression

The paper uses the tool of STATA12.0 and EVIEWS6.0 to realize the data parameter estimation. Without taking the threshold effect of the aviation mileage into consideration, the paper uses the population at the departure and the destination, GDP, the pollution level, the railway operation time at the departure and the destination, whether it is the main railway line, the speed of the railway line to conduct the ordinary panel regression to the aviation flight number and the aviation passenger volume respectively, to describe the impact of the railway on the field of aviation in China.

If using the panel data to estimate the influence of the development of the railway to the aviation, without taking the threshold effect of the aviation mileage into consideration, we can see from the estimation results of panel regression (Table 2) that the impact using fixed effect model of the railway to the passenger volume and the flight number generates is larger than using random effect model. The coefficients of the fixed effect model of speed, highspeed and railtime are larger than those in the random effect model ($0.281 > 0.240$, $-0.271 > -0.272$, $-0.118 > -0.151$). Artery's influence on the aviation passenger volume in the fixed effect model is not significant. In the model 2, the coefficient of *highspeed* ($-0.092 > -0.114$), and the impact of other variables to the flight number is not significant. The economic aggregates at the departure and the destination have a large influence on aviation industry. GDP's influence on the aviation passenger volume in the fixed effect model and in the random effect model is 0.738 and 0.735 respectively and its impact on the flight number also reaches 0.712 and 0.690 respectively, which reflects that economy is the foundation of the development of the aviation industry. The more population the departure and the destination has, the more choice the passengers have when selecting the means of transportation. Most of the explanatory variables pass the test at the 10% significant level. Test for heteroscedasticity within groups in the model shows that the heteroscedasticity is significant, and the model needs to be further improved.

3.2.2. Panel threshold regression model of China's railway

3.2.2.1. Existing test for panel threshold. The simulated distribution is obtained after the design of bootstrap for 20,000 times. In Table 3 the paper has listed the critical values and the statistical values at the significant level of 1%, 5% and 10%. To determine whether one, two or three thresholds exist in the panel threshold regression mode, reflecting whether the nonlinear transformation behavior of the railway taking the aviation mileage as the threshold variable exists to aviation.

As can be seen from Table 3, in Model 1, the P value of the single threshold and the double threshold variable is 0, which is statistically significant. At the significant level of 1%, 5% and 10%, the critical value of F statistic with two thresholds is greater than that of the single threshold F Statistics ($6.77173 > 6.71058$, $3.87504 > 3.86944$, $2.69548 > 2.68088$), while the P value of the three threshold is relatively large. Thus, we can identify that the double threshold effect significantly exists in the model. That is to say, the effect regression model with two thresholds of the railway to aviation which regards the aviation mileage as the threshold variable exists.

Table 3
Results of existing test for panel threshold.

	Type	F-critical1%	F-critical5%	F-critical 10%	F-stat	Prob.
Model1	Single threshold	6.71058	3.86944	2.68088	33.80300	0.00000
	Double threshold	6.77173	3.87504	2.69548	19.13190	0.00000
	Triple threshold	7.18023	4.11250	2.91468	12.55330	0.00130
Model2	Single threshold	6.74557	3.82156	2.71307	60.78410	0.00000
	Double threshold	6.55865	3.77372	2.68959	24.75090	0.00000
	Triple threshold	6.63618	3.81704	2.66746	6.67760	0.00980

Table 4
Estimation of the threshold value.

	Threshold parameter	Estimate	95% confidence interval
Model 1	**Ln** *miles1*	6.1947	[6.1473, 6.4632]
	Ln *miles2*	7.0316	[7.0305, 7.0948]
Model 2	**Ln** *miles*	6.4158	[6.4053, 6.4632]

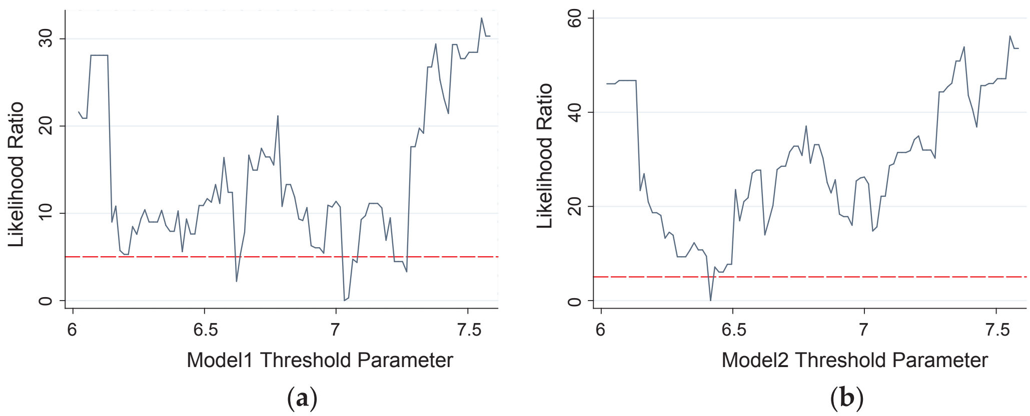
In Model 2, the P value of the single threshold and the double threshold variable is 0, which is statistically significant. At the significant level of 1%, 5% and 10%, the critical value of single threshold F statistic is greater than that of the F Statistics with two and three thresholds (6.74557 > 6.63618 > 6.558653.82156 > 3.81704 > 3.773722.71307193.095 > 2.68959 > 2.66746). Thus, we can identify that the single threshold effect significantly exists in the model. That is to say, the effect regression model with one threshold of the railway to aviation which regards the aviation mileage as the threshold variable exists.

Table 4 shows the estimation of the threshold value. The threshold equals to the aviation mileage when the likelihood ratio is 0. In the model 1, the two threshold values of the aviation mileage (Ln miles) are 6.1947 and 7.0316 respectively, and its 95% confidence intervals are [6.1473, 6.4632], [7.0305, 7.0948], corresponding to the range of the threshold variable covered by the likelihood ratio function value near the horizontal line in the graph. The confidence interval of the threshold is shown in Fig. 1(a) The Threshold Confidence Interval Graph of Aviation Passenger Volume. In Model 2, the single threshold value of the aviation mileage (Ln miles) is 6.4158, and its 95% confidence interval is [6.4053, 6.4632], corresponding to the range of the threshold variable covered by the likelihood ratio function value near the horizontal line in the graph. The confidence interval of the threshold is shown in Fig. 1(b) The Confidence Interval Graph of the Flight Number, and they are all under the 5% confidence level.

3.2.2.2. Panel threshold regression estimation. The relating interval explanation variables are the key point of the panel threshold regression. To the variables of railway speed, the network of the main railway lines, the economic level, the population and the environment pollution, the paper conducts the panel threshold regression to the two models. Results of the estimation can be seen in Table 5.

In Model 1, the control variable is the aviation mileage. When the aviation mileage (Ln miles) is lower than 6.1947 (which means the miles equal to 490.1444 km), the elasticity of the railway operation time is 0.1931 (since the railway operation time is a restriction factor of the aviation, and the larger the positive influence is, the stronger the restriction will be); When the aviation mileage (Ln miles) is higher than 6.1947 but lower than 7.0316 (which means the miles equal to 1131.843 km), the elasticity of the railway operation time will decline to −0.1157; when the aviation mileage (Ln miles) is higher than 7.0316, the railway operation time will exert a negative influence on the aviation passenger volume and its elasticity coefficient is −0.3343. In other words, when the aviation mileage is lower than 490.1444 km, the substitutability effect of China's railway transport to the aviation industry reaches its maximum; when the a mileage is from 490.1444 to 1131.843 km, the substitutability of the railway to aviation industry declines, and people choose their ways for traveling will be according to the actual situation; when the aviation mileage is larger than 1131.843 km, the railway of China has a significant influence to the aviation, which promotes the aviation industry. The aviation corporations shall improve the domestic long-distance service, increase the flight number and optimize the aviation operation network. The government shall strengthen their delivery capacity with short distance, which helps to build a harmonious development of the railway and the aviation.

Interval independent explanatory variables include economic level, population, environmental pollution, railway speed, the network of the main railway lines, and whether it is high-speed railway. The aviation transport industry is mainly affected by the economic development. Its elasticity coefficient is 0.7308, which means that the development of the aviation industry is mainly for high income groups. The elasticity of the environmental pollution and the railway speed elasticity are positive, indicating that it



(a) (b)

Fig. 1. The confidence interval graph of the panel threshold regression of China's railway.

Table 5
Estimation results of panel threshold regression.

	Variable	Coef.	Std.	t	Prob.
Model 1	**Ln** *GDP*	0.7308	0.0247	29.5937	0.00000
	Ln *population*	−0.0256	0.0856	−0.2996	0.7645
	Ln *pollution*	0.0429	0.0247	1.7382	0.0823
	artery	0.0646	0.1551	0.4162	0.6773
	Ln *speed*	0.2447	0.1024	2.3891	0.017
	highspeed	−0.2813	0.0382	−7.3625	0.00000
	Ln *railtime* (**Ln** *miles* $\leqslant$ 6.1947)	0.1931	0.0779	2.4796	0.0132
	Ln *railtime* (6.1947 < **Ln** *miles* $\leqslant$ 7.0316)	−0.1157	0.0516	−2.2407	0.0252
	Ln *railtime* (**Ln** *miles* $\geqslant$ 7.0.0316)	−0.3343	0.0606	−5.5209	0.00000
Model 2	**Ln** *GDP*	0.70820	0.02220	31.84110	0.00000
	Ln *population*	−0.17900	0.07700	−2.32500	0.02020
	Ln *pollution*	0.00730	0.02220	0.33000	0.74,140
	artery	−0.03100	0.13970	−0.22210	0.82430
	Ln *speed*	−0.00900	0.09220	−0.09720	0.92260
	highspeed	−0.11320	0.03440	−3.29310	0.00100
	Ln *railtime* (**Ln** *miles* < 6.4158)	0.26860	0.05840	4.59960	0.00000
	Ln *railtime* (**Ln** *miles* > 6.4158)	−0.10520	0.04590	−2.29050	0.02210

promotes the growth of the aviation passenger volume, and their elasticity are 0.0429 and 0.2447; The elasticity that whether it is the high-speed railway is negative, indicating high-speed railway will hinder the increase of the aviation passenger volume, and its elasticity is −0.2813, the mean population at departure and destination, whether it is the main routes has no direct influence on aviation passenger volume.

In Model 2, when the aviation mileage (Ln miles) is lower than 6.4158 (which means miles are lower than 611.4297 km), the elasticity of the railway operation time is 0.26860; when the aviation mileage (Ln miles) is higher than 6.4158, the elasticity of the railway operation time will decline to −0.10520, indicating that when the aviation mileage turns out to be lower than 611.4297 km, the shock of the aviation mileage to the flight number reaches its maximum; when the aviation mileage is higher than 611.4297 km, the influence of the aviation mileage to the flight number at the departure and the destination decreases, which is helpful to the development of the aviation industry.

As for other explanatory variables, the economic development at the departure and the destination has the largest impact on the flight number, and its elasticity coefficient is 0.70820; the elasticity of the population at the departure and the destination and whether it is high-speed railway are negative, which are −0.17900 and −0.11320 respectively, indicating it has negative influence on the flight number. The flight number is not directly affected by the environmental pollutant, whether it is the main railway lines, and the railway operation speed.

By conducting P test, most of the variables are significant at the confidence level of 10%, indicating that two sets of nonlinear panel threshold regression model is better than the linear panel regression model.

3.2.2.3. Interval analysis for panel threshold regression. The empirical results of the two models show that the nonlinear transformation taking the aviation mileage as the threshold variable exists in the elasticity of economic level, population, environmental pollution, railway speed, and whether it is high-speed railway. The panel data are different for different lines and different aviation mileage, which reflects the differences in the contribution of the railway to aviation industry and in aviation mileage. The paper lists the airlines whose aviation mileages are lower than 490.1444 km, the airlines that bear the biggest shock from the railway in China.

As can be seen from Table 6, there are 17 airlines in the aviation industry bearing the biggest shock. They are mainly distributed in the central and western regions in China where the economy is less developed. Due to its poor economy, people living in the region will face greater economic pressure when selecting air travel for transport tool. Moreover, since the choices of transport tools such as aviation and highway are so limited, it will be more convenient for them to choose railway for traveling. Only a few airlines are distributed in the coastal areas whose economy is relatively developed. Due to the opening of the high-speed railway, it has been very fast as a tool for traveling. The impact of high-speed railway on the aviation will be given a detailed analysis as bellow.

Table 6
Airlines bearing the biggest shock from China's railway and the aviation mileage.

Origin–Destination	Miles	Origin–Destination	Miles	Origin–Destination	Miles
Kunming-Lijiang	314	Kunming-Guiyang	412	Guilin-Shenzhen	467
Dalian-Qingdao	338	Beijing-Taiyuan	431	Kunming-Mangshi	470
Shanghai-Wenzhou	358	Xishuangbanna-Kunming	450	Shenzhen-Xiamen	480
Wuyishan-Xiamen	362	Urumqi- Ghulja	462	Chengdu-Kunming	486
Dalian-Tianjin	364	Guangzhou-Haikou	464	Lanzhou-Xi'an	489
Guangzhou-Guilin	371	Haikou-Shenzhen	467		

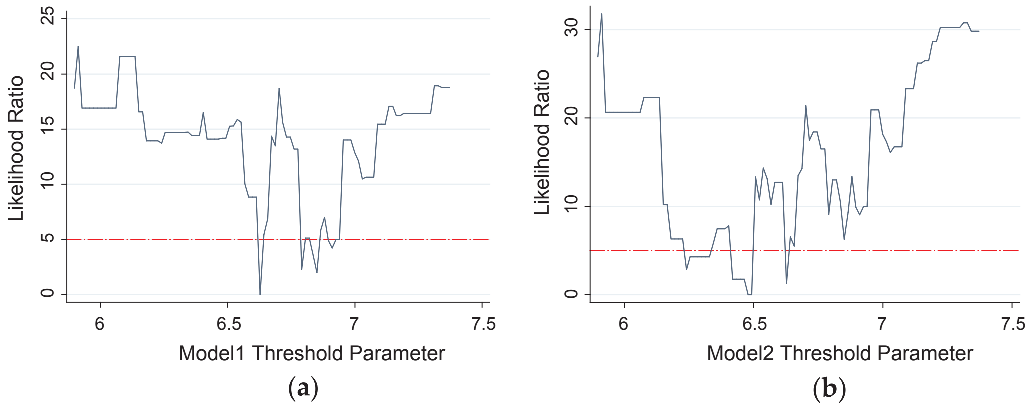


Fig. 2. The confidence interval figure of the panel threshold regression of China's high-speed railway.

3.3. The shock effect of China's high-speed railway on the aviation transport industry

From the model of the Chinese railway on aviation transport industry, the paper chooses the routes containing the high-speed (more than 250 km/h) railway, and data of 67 routes in 27 major cities of China are obtained. Since the existing high-speed railway are all located in network of the main railway lines, making the variable that whether it is the main railway line not significant in shocking the aviation transport industry, so it is deleted from the model. According to the panel threshold regression theory, the paper chooses the mean of the economic aggregates at the departure and the destination, environmental pollution, the aggregate population, the operation speed of high-speed railway as explanatory variable, the operation time as the control variable, and the aviation mileage as the threshold variable, to build the panel regression model of China's high-speed railway.

Design the bootstrap for 20,000 times. By conducting F statistic, we know that two-threshold and one-threshold effect panel regression exist in Model 1 and Model 2 respectively. The threshold confidence interval graph of aviation passenger volume and aviation passenger volume are shown in Fig. 2(a) and 2(b). We can see from the graph that the threshold values are all below the level of 5%.

The paper conducts the panel threshold regression by using STATA. The estimation results are shown in Table 7. In the shock effect model to the aviation passenger volume (Model 1), when the aviation mileage (Ln miles) is lower than 6.5527 (which means the miles equal to 701.1347 km), the elasticity of the railway operation time is 0.2177, which is higher that the shock of the railway to the aviation industry. When the aviation mileage (Ln miles) is higher than 6.5527 but lower than or equal to 6.6272 (which means the miles equal to 755.3642 km), the elasticity of the railway operation time will climb to 0.5107. When the aviation mileage (Ln miles) is higher than 6.6272, the influence of the high-speed railway operation time to the aviation passenger volume is not significant. The results can also be explained as follows. When the aviation mileage is lower than 701.1347 km, a certain substitution effect to the aviation industry exists; when the aviation mileage is from 701.1347 km to 755.3642 km, the substitution effect to the aviation industry reaches the maximum, which is helpful in developing the high-speed railway; when the aviation mileage is higher than 755.3642 km, China's high-speed railway has no direct influence on aviation transport. Compared with China's railway, China's high-speed railway has a more obvious shock to the aviation transport.

Interval independent explanatory variables include economic level, population, environmental pollution and high-speed railway speed. The aviation transport industry is mainly affected by the economic development. Its elasticity coefficient is 0.7999, which means that the development of the aviation industry is mainly for high income groups. The elasticity of the high-speed railway is

Table 7
Estimation results of panel threshold regression of China's high-speed railway.

Variable	Coef.	Std.	t	Prob.
Ln *GDP*	0.7999	0.0353	22.6309	0.0000
Ln *population*	−0.3186	0.1379	−2.3106	0.0211
Ln *pollution*	0.0485	0.0393	1.2354	0.2170
Ln *speed*	0.1116	0.1182	0.9446	0.3451
Ln *railtime* (**Ln** *miles* ⩽ 60.5527)	0.2177	0.0594	3.6662	0.0003
Ln *rail*time (60.5527 < **Ln** *miles* ⩽ 60.6272)	0.5107	0.1005	5.0833	0.0000
Ln *railtime* (**Ln** *miles* ⩾ 60.6272)	0.0563	0.0551	1.0223	0.3069
Ln *GDP*	0.7056	0.0306	23.0572	0.0000
Ln *population*	−0.6196	0.1198	−5.1702	0.0000
Ln *pollution*	0.0617	0.0340	1.8178	0.0694
Ln *speed*	−0.0225	0.1023	−0.2198	0.8261
Ln *railtime* (**Ln** *miles* ⩽ 60.4782)	0.2828	0.0570	4.9577	0.0000
Ln *railtime* (**Ln** *miles* > 60.4782)	0.0213	0.0464	0.4595	0.6460

Table 8
Airlines bearing the biggest shock from China's high-speed railway and the aviation mileage.

Origin–Destination	Miles	Origin–Destination	Miles	Origin–Destination	Miles
Dalian-Qingdao	338	Hangzhou-Wuhan	568	Beijing-Wuhan	676
Shanghai-Wenzhou	358	Nanchang-Shanghai	596	Shanghai-Wuhan	676
Dalian-Tianjin	364	Beijing-Shenyang	610	Shenyang-Qingdao	689
Guangzhou-Guilin	371	Hangzhou-Qingdao	644	Guangzhou-Fuzhou	691
Beijing-Taiyuan	431	Beijing-Qingdao	646	Changsha-Nanjing	702
Guilin-Shenzhen	467	Changsha-Xiamen	662	Ningbo-Qingdao	707
Shenzhen-Xiamen	480	Fuzhou-Nanjing	665	Hangzhou-Xiamen	717
Guangzhou-Xiamen	515	Changsha-Guiyang	667	Shanghai-Jinan	750

higher than the shock of China's railway to the aviation ($0.7999 > 0.7308$), which also means that the high-speed railway also belongs to the high-income groups. The elasticity of the environmental pollution is -0.3186, which is negative, indicating that the high-speed railway will hinder the increase of the airline traffic. The mean of the population at the departure and the destination and the high-speed railway speed have no direct influence on the aviation passenger volume.

In the shock effect model to the aviation passenger volume (Model 2), when the aviation mileage (Ln miles) is lower than or equal to 6.4782 (which means the miles equal to 650.7985 km), the elasticity of the railway operation time is 0.26860; when the aviation mileage (Ln miles) is higher than 6.4782, which means when the miles is more than 650.7985 km, China's high-speed railway has no direct influence on the aviation transport.

As for other explanatory variables, the economic development at the departure and the destination has the largest impact on the flight number, and its elasticity coefficient is 0.7056; the elasticity of the population at the departure and the destination is negative, which is -0.6196 and -0.11320 respectively, indicating it has negative influence on the flight number. The elasticity of the air pollution level at the departure and the destination is positive, which is -0.0225; the high-speed railway has no direct influence on the flight number.

In Table 8, the paper lists the airlines whose aviation mileages are lower than 755.3642 km, the airlines that bear the biggest shock from the railway in China. It can be seen from the Table 8 that the aviation mileages of 24 airlines are lower than the threshold value. The main areas that China's high-speed railway influences the aviation are: the areas around Bo Hai, Yangtze River Delta and Zhuhai Delta. As for the main high-speed railway lines, "Harbin-Dalian Railway Passenger Dedicated Line", "Beijing-Hong Kong Railway Passenger Dedicated Line", and "Hangzhou-Fuzhou-Shenzhen Railway Passenger Dedicated Line" have a larger influence on the aviation. The 4 airlines from 701.1347 km to 755.3642 km are bearing the largest influence from the high-speed railway. The main reason is that the railway network in China enjoys its rapid growth and gets improved gradually. Although the high-speed railway is largely influenced by the economy to some extent, but since the coastal areas are more developed, the price of the high-speed railway exerts less influence on the passengers of the region when selecting the means of transportation; while the central and western area in China are less developed, the high-speed railway lines are deficient, which makes a weaker influence of the high-speed railway in the region.

4. Conclusions

The paper establishes the panel threshold regression model containing railway indicator, economic indicator, demographic indicator and environmental indicator, to describe the linear and nonlinear influence of China's railway and high-speed railway on the aviation transport industry under each aviation mileage. By conducting empirical analysis, the conclusions can be summarized as follows. To the airlines in different areas, the railway and high-speed railway will generate positive shock on the aviation transport industry when the aviation mileage is small. When the aviation mileage is getting larger, China's railway will promote the development of the aviation transport industry to some extent. Moreover, the economic development has the largest influence on the aviation industry.

As can be seen from the panel threshold regression model of China's railway's influence effect on the aviation industry, when the aviation mileage is lower than 490 km, China's railway has a substitution effect to the aviation passenger volume, with an elasticity coefficient of 0.1931; when the distance between the departure and the destination is further, China's railway will promote the development of the aviation to some extent. At the same time, when the aviation mileage is lower than 611 km, China's railway will exert a positive shock on the flight number. When the aviation mileage is more than 611 km, the flight number at the departure and the destination will increase as the aviation mileage increases. The elasticity of the level of the economic development at the departure and the destination to the aviation industry is 0.7308 and 0.7082 respectively, making it a key factor influencing the development of the aviation.

As can be seen from the panel threshold regression model of China's high-speed railway on the aviation industry, when the aviation mileage is lower than 701 km, China's high-speed railway has a substitution effect to the aviation passenger volume, with an elasticity coefficient of 0.2177; when the aviation mileage is from 701 km to 755 km, the shock from the high-speed railway to the aviation passenger volume reaches its maximum, with an elasticity coefficient of 0.5107. When the aviation mileage is more than 755 km, the influence of China's high-speed railway to the flight number at the departure and the destination is not significant. In the model of the flight number, when the aviation mileage is lower than 651 km, the flight number will receive a positive shock; when the aviation mileage is higher than 651 km, the direct influence of China's high-speed railway to the flight number at the departure and the destination is not significant. The elasticity of the level of the economic development at the departure and the destination to the aviation industry is 0.7999 and 0.7056 respectively. The level of the economic development is a key factor influencing the development of the aviation industry. Compared with China's railway, China's high-speed railway's influence on the aviation industry is more obvious, reflecting a larger shock effect of China's high-speed railway on the aviation industry. That is to say, the aviation industry is bearing quite a large shook from China's high-speed railway. The conclusions in the paper will not only promote the harmonious development of the aviation industry and the railway and high-speed railway, but also help make the plan for the transportation network operation more reasonable. Besides, it provides an important theoretical basis for the sustainable development of the economy during the "13th Five-Year plan".

The rapid development of railway transportation in our country not only promotes the connection between different economic centers, but also promotes the economic effect of high-speed railway. In response to the rapid development of high-speed railway, the air transport industry to take appropriate policies. First, the adjustment of air operations model, in the face of the eastern central region by high-speed rail direct impact of 755 km below the short-haul routes to reduce the capacity of the straight-line configuration, increase the transit route configuration. Strengthen the capacity of 755–1000 km route arrangements, improve flight frequency, enhance service quality Second, to achieve high-speed rail and aviation complement each other. Enhance cooperation with the railway to achieve win–win cooperation, mutual benefit, information sharing, benefit-sharing. Finally, we should seize the market opportunities between economic belt formation and grasp the role of air transport between the Yangtze River Delta, the Pearl River Delta, the Bohai Sea economic belt, the northeast old industrial base and the Chengdu-Chongqing Economic Belt.

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Author Contributions

Zhe George Zhang and Zenghui Liu provided valuable comments. Other authors contributed equally to this work.

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