Analysis of the influence of high-speed railway on economic development

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Abstract—This paper selects the data of 12 years of operation of China's high-speed railways for empirical analysis. It constructs a VAR model between high-speed railway construction and economic development, and introduces two intermediate variables that make railway transportation capacity and human capital. Through the Johansen cointegration relationship test and Granger causality test, this paper can find that there is a long-term equilibrium relationship between high-speed railway construction and economic development. The construction of high-speed railways promotes economic development through the transmission multiplier effect. Finally, forecast the operating mileage of high-speed railways in the next three years. And then put forward corresponding suggestions for the current interactive relationship between high-speed railway and economic development.

1. INTRODUCTION
In order to meet the rapidly growing demand for passenger transportation, the railway network has formed an "eight vertical and eight horizontal" intercity railway network on the basis of the "four vertical and four horizontal" high-speed railways. The railway network connects provincial capital cities across the country and covers large cities with a population of more than 500,000. A total of about 41,000 kilometers of new lines are planned to be constructed, of which 16,000 kilometers will be built for passenger dedicated lines [1].

In China's infrastructure investment, railway investment accounts for up to 23%, with rapid growth in recent years. The annual investment of railway in 2010 is more than ten times that of 2003 [2]. A large part of the investment of the railway sector is used for the upgrading of existing railway lines and the construction of high-speed rail. The emergence of high-speed rail shortens the travel time between cities and speeds up economic exchanges between cities. Therefore, it is of practical significance to explore the relationship between high-speed railway construction and economic development. Ease of Use

2. LITERATURE REVIEW
The impact of high-speed rail on regional economic growth is a research direction that scholars are interested in. However, current scholars mostly focus on the relationship between railway transportation and national economic development after the opening of the railway. Some scholars believe that the
opening of high-speed rail can promote economic development. For example, Dong YM and Zhu YM[3] found that the construction of high-speed rail promotes employment in high-speed rail cities and increases wages in high-speed rail cities, which has a positive effect on overall economic growth. Chen FL et al. [4] believe that the development of high-speed rail can reduce the urban-rural income gap by accelerating population and capital flows, thereby promoting economic development. Chen G [5] used Structural Equation Modeling (SEM) to study the internal relationship between Spanish high-speed rail construction investment and economic growth. The research showed that high-speed railway construction investment has a positive impact on provincial economic growth, boosting GDP, and increasing employment levels. There are also a small number of scholars who believe that the opening of high-speed rail may not necessarily promote economic development. For example, Qin [6] conducted a study on China’s railway network and believed that the development of high-speed rail does not necessarily have a positive impact and may harm the economy. Baum SN et al [7] found that the development of central cities along the high-speed rail has a negative impact on surrounding cities, and even widens the economic gap, thus creating a tunnel effect.

Therefore, in order to explore the relationship between high-speed railway construction and economic development, this article separates high-speed rail construction from the railway transportation industry and takes high-speed railway construction, railway transportation capacity, human capital and economic development as the research objects. Construct a four-variable autoregressive model of these four variables, and use cointegration analysis and Granger causality analysis to verify the correlation between the four.

3. RESEARCH METHODS

3.1. Mean square deviation weighting method

There are three main types of weighting methods for evaluation indicators, namely subjective weighting method, objective weighting method and subjective and objective weighting method. The mean square deviation weighting method used in this article belongs to the objective assignment method.

The mean square deviation is the standard deviation, and the standard deviation can reflect the degree of dispersion of the data set. The main principle of the mean square error weighting method is: the relative weight coefficient of each index depends on the relative dispersion degree of the evaluation value of each program under this index [8]. If the scatter degree of the evaluation value of each program under a certain index is greater, it indicates that the difference of each program under the evaluation index is greater, and the index should be given a larger weight coefficient, and vice versa. The steps of the mean square deviation weighting method are as follows [9]:

Assuming that the set of years is \( A = \{A_1, A_2, \ldots, A_m\} \), and the evaluation index set is \( Y = \{Y_1, Y_2, \ldots, Y_n\} \), then the attribute matrix of the year \( A \) index \( Y \) is denoted as \( (A)_{m \times n} = (y_{ij})_{m \times n} \), firstly, the established judgment matrix \((A)_{m \times n}\) is standardized to obtain the standardized matrix.

\[ Z = (Z_{ij})_{m \times n} \]  (1)

Mean value of random variable:

\[ E(Y_j) = \frac{1}{n} \sum_{i=1}^{n} z_{ij} \]  (2)

Mean square deviation:

\[ \sigma(y_j) = \sqrt{\sum_{i=1}^{n} (z_{ij} - E(y_j))^2} \]  (3)

Weight coefficient:

\[ w_j = \frac{\sigma(y_j)}{\sum_{j=1}^{n} \sigma(y_j)} \]  (4)

The comprehensive score of each variable was calculated:

\[ G_t = \sum_{j=1}^{n} (w_j y_j) \]  (5)
3.2. Vector Autoregressive model

The Vector Autoregressive model (VAR model) was introduced into economics by Sims (1980), which promoted the wide application of economic system dynamic analysis [10]. This model is used to predict interrelated economic time series systems and analyze the dynamic impact of random disturbances on the variable system, thereby further explaining the impact of economic shocks on economic variables. The expression of the VAR model with lag order $p$ is:

$$ y_t = A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + B x_t + \mu_t $$

Among them, $y_t$ is the $k$-dimensional endogenous variable vector; $x_t$ is the $d$-dimensional exogenous variable vector; $\mu_t$ is the $k$-dimensional error vector; $A_1, A_2, \cdots, A_p, B$ are the coefficient matrices to be estimated.

4. Econometric model and empirical analysis

4.1. Data sources and research samples

The first high-speed railway opened in China was the Beijing-Tianjin high-speed railway, which was put into operation in 2008. Therefore, this paper selects data from 2008 to 2019 for empirical analysis. The two intermediate variables of railway transportation capacity and human capital are added to construct a four-element vector autoregressive model (VAR) to explore the mutual influence between high-speed railway construction and economic development. Because it is difficult to find high-speed railway investment data and it is difficult to separate from the annual railway investment data. Therefore, this article takes the annual increase in high-speed railway operating mileage as the economic input variable, which is recorded as MIL. Select railway transportation capacity and human capital as the intermediate variables of high-speed railway construction and economic development, and record them as TRANS and MANP respectively. Railway transportation capacity refers to passenger volume, freight volume and passenger and freight turnover; Human capital includes the total urban population, urban population, employed personnel, and the number of patent applications; since economic development is the sum of various economic sectors composed of various industries, the measurement of economic development should not be based on the indicator of GDP. For measurement. The specific measurement indicators are shown in the following table:

| variable                      | Metrics                                                                 |
|-------------------------------|-------------------------------------------------------------------------|
| High-speed railway construction| Annual high-speed railway operating mileage (km)                         |
| Railway transportation capacity| Passenger volume (10 thousand)                                           |
|                               | Cargo volume (10 kt)                                                    |
|                               | Passenger turnover (10 thousand)                                        |
|                               | Freight turnover (10,000 kt)                                            |
| human capital                 | Total urban population (10 thousand)                                     |
|                               | Urban population (10 thousand)                                          |
|                               | Number of employees (10 thousand)                                       |
|                               | Number of patent applications (pieces)                                  |
| economic development          | GDP (100 million yuan)                                                  |
|                               | Financial revenue (100 million yuan)                                    |
|                               | Per capita disposable income of urban residents (yuan)                  |
|                               | Total value of imports and exports (100 million yuan)                   |
|                               | Total output value of construction industry (100 million yuan)          |
|                               | Total post and telecommunications business (100 million yuan)            |
|                               | Domestic tourism (10 thousand)                                          |
|                               | Total domestic tourism expenditure (100 million yuan)                   |
The data comes from China Statistical Yearbook and Forward-looking Economist. Firstly, the data is processed, and the mean square error assignment method of formula (1) to formula (4) is used to determine the weight of each index of railway transportation capacity, human capital and economic growth, and the comprehensive value of each variable is calculated according to formula (5).

4.2. Stationarity test method

If it is not stationary, the variables are differentiated to obtain a stationary sequence and then construct the VAR model. [11]. Use LMILE, LTRANS, LMANP, and LECON to represent the logarithm of high-speed railway construction, railway transportation capacity, human capital and economic development, and use EViews8 to draw the sequence diagram of each variable as shown in Figure 1.

![Time sequence diagram of logarithmic variables](image_url)

**Figure 1. Time sequence diagram of logarithmic variables.**

It can be seen from Figure 1 that LMILE, LTRANS, LMANP, LECON have a certain time trend, and the change trend is roughly the same, so these variables should have a certain relationship. In order to avoid the occurrence of "false regression" phenomenon, the stationarity test of each variable should be carried out before analyzing the time series data. In general, the stationarity test is the unit root test of the data, and the unit root test mainly uses the ADF test method and the pp test method. This paper chooses the ADF test method to use Eview software to perform unit root test on LMILE, LTRANS, LMANP, and LECON. The results show that these sequences are not stable. Therefore, the four groups of variables LMILE, LTRANS, LMANP, and LECON are processed by first-order difference processing, which are respectively marked as DLMILE, DLTRANS, DLMANP, and DLECON, and the ADF test is performed again. The test results show that DLMILE, DLTRANS, DLMANP, and DLECON are all stable time series.

4.3. Cointegration test

Although the original series is non-stationary, because the linear combination may be able to offset the random trends in the four time series, there may be some kind of stationary linear combination between them. Regress LECON, LMILE, LTRANS and LMAN, and apply the Cointegration Regression Durbin-Watson (CRDW) test to the obtained Durbin-Watson d statistic [12]. The test results are shown below.

\[
LECON = -1.356930 + 0.058127LMILE + 0.585393LTRANS + 0.412394LMANP \\
\delta = 0.533768 \quad R^2 = 0.996610
\]  

(7)

In the above formula, \( \delta = 0.533768 \) is higher than the critical value at the 1% level, indicating that there is a long-term equilibrium relationship between LMILE, LTRANS, LMANP, and LECON. Balanced relationship. From the cointegration equation, it can be seen that \( R^2 = 0.996610 \) indicates that the model is well-fitted and the overall explanatory power is strong. And the co-integration equation determines that in the medium and long-term process, when high-speed railway construction increases by 1%, economic development will increase by 0.058%.

Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:
4.4. **VAR model**

Because of the small amount of data, a VAR model with a lag period of 2 was established. Use EVIEW software to obtain a quaternary VAR model between high-speed railway construction, railway transportation capacity, human capital and economic development.

The R² of each equation is above 0.98, indicating that these four equations have a good fitting effect. And the residual method is tested and there is no autocorrelation, and the test model results are stable. Therefore, Granger causality test can be performed.

4.5. **Granger causality test**

It can be seen from the above that there is a long-term equilibrium relationship between high-speed railway construction, railway transport capacity, human capital and economic development, but whether this relationship is a causal relationship still needs further examination. If a variable is affected by the lag of other variables, it is said that there is a Granger causality between them [13].

Use Eview8 to perform Granger causality test on the above four variables, and the test results are shown in the following table.

| H₀                        | F-Statistic | Prob.  |
|---------------------------|-------------|--------|
| LMILE does not Granger Cause LECON | 15.1742     | 0.0047 |
| LECON does not Granger Cause LMILE | 7.20625     | 0.0337 |
| LTRANS does not Granger Cause LMILE | 0.98462     | 0.4360 |
| LMILE does not Granger Cause LTRANS | 18.9795     | 0.0046 |
| LMANP does not Granger Cause LMILE | 1.51776     | 0.3054 |
| LMILE does not Granger Cause LMANP | 9.40766     | 0.0154 |
| LTRANS does not Granger Cause LECON | 7.28737     | 0.0322 |
| LECON does not Granger Cause LTRANS | 1.39207     | 0.3307 |
| LMANP does not Granger Cause LECON | 10.2765     | 0.0112 |
| LECON does not Granger Cause LMANP | 5.79679     | 0.0427 |
| LMANP does not Granger Cause LTRANS | 2.37565     | 0.1883 |
| LTRANS does not Granger Cause LMANP | 3.99027     | 0.0808 |

According to the Granger causality test, at the 5% significance level, LMILE and LECON, LECON and LMANP all have two-way causality. It reveals the mutual causality between high-speed railway construction and economic development. In addition, there is a one-way causal relationship from LMILE to LTRANS, LMILE to LMANP, and LTRANS to LECON at the 5% significance level. It shows that the construction of railway lines has stimulated the development of railway transportation capacity and human capital, and the railway transportation capacity has promoted economic development. It should be noted that at the 10% significance level, LTRANS and LMANP have a one-way causal relationship. It shows that railway transportation capacity also has a certain promoting effect on human capital.

4.6. **Forecast**

Using China's high-speed railway operating mileage data in 2008 and 2019, the establishment of a quadratic regression model with one yuan is as follows:

\[ y = -6090425 + 3032.36t \]
Where \( y \) represents the operating mileage of Chinese railways (\( \text{my} \)), and \( t \) represents the time year (\( t=2008,\ldots,2019 \)). The \( R^2=0.979803 \) of the one-variable regression model indicates that the model has a high degree of fitting to the time series. The data from 2020 to 2022 is predicted by using this model, as shown in the following table.

| years | 2020      | 2021      | 2022      |
|-------|-----------|-----------|-----------|
| High-speed railway operating mileage | 34942.26  | 37974.62  | 41006.98  |

The error between the simulated prediction data and the actual data is within an acceptable range [14], and Theil=0.040591<0.05 in the prediction fitting indicates that the prediction data has high credibility.

5. CONCLUSIONS
By constructing a VAR model to study the relationship between high-speed railway construction and economic development, this paper shows that high-speed railway construction and economic development are Granger reasons for each other. According to the data from the “Report on China’s High-speed Railway Industry Market Status Quo and Future Development Prospects 2020-2026”, the national railway network is expected to reach 175,000 kilometers in 2025, of which 38,000 kilometers are high-speed railways. At the end of 2019, China’s high-speed railway operating mileage has reached 35,000 kilometers. According to the above forecast, we can know that we can complete the task ahead of schedule. In the long run, every 1% increase in high-speed railway construction will increase economic development by 0.058%.

The relevant suggestions are as follows: High-speed railway projects should consider small and medium-sized cities and remote poor areas. In order to balance regional development, narrow the gap between backward and coastal areas, and strengthen national unity, the central government’s investment should be tilted towards small and medium-sized cities and backward areas.

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