A causality analysis between spatial differences in economic development and transportation development in China

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Abstract. This paper analyzes the spatial differences in transportation development and regional economic development in the whole and eight economic regions of China from 1997 to 2017, as well as their Granger causality. The basic conclusions include that the spatial differences in national highway and railway development is more significant than that in economic development. The transportation development of each province in the Northwest Economic Zone is very different. The imbalance of economic development in the middle reaches of the Yangtze River and Southwest Economic Zone is increasing. There is a bidirectional causal relationship between the spatial differences of the highway development and economic development for the country. Also, a one-way causal relationship from the unbalanced development of economy to the unbalanced development of railway is tested in Northwest Economic Zone, and in the Eastern and Southern coastal economic zones, the unbalanced development of highways Granger cause the unbalanced development of economy.

1. Introduction

Strengthening the construction of transportation infrastructure is an important measure for a country to narrow the regional development gap. However, many facts and studies indicate that the improvement of transportation conditions will strengthen the "siphon effect" of developed regions, thus aggravating the unbalanced development among regions\(^1\)-\(^2\). As a big country in economy and geography, China has double significant spatial differences in the level of transportation and economic development. Unbalanced and inadequate development has become the main manifestation of social contradictions in China, which is not conducive to the sustainable development of the future economy. Then, with the improvement of China's transportation network over the years, how does the spatial differences in regional transportation development and economic development change? What kind of interaction exists in it? It is of practical significance and reference value for the Chinese government to analyze and study the above problems.

Numerous documents show scholars' attention to the regional economic development differences, they study different aspects of the differences from different countries and regions, including gap analysis, cause analysis, strategic countermeasures. For example, Kosyrkeva analyzes the process and trend of economic development differentiation in the EU based on per capita GDP\(^3\). Démurger believes that institutional policy, geographical location and infrastructure allocation are the significant factors that cause regional economic differences\(^4\). Through empirical analysis, Sun B, et al. think that
the multi center urban planning policy may not be as useful as the planners and policy makers to
eliminate regional differences[5]. There are various methods to measure regional economic differences,
including the comprehensive index, the coefficient of variation, Gini coefficient, as well as the scale
nested analysis model, the spatial correlation analysis model and so on, which provide many mature
methods for our research.

As the "forerunner" of social and economic development, the fairness of spatial allocation of
transportation infrastructure has been paid more and more attention by scholars. Most of the research
methods on the regional differences in transportation development are similar to the measurement
methods of economic development differences. Cao uses the natural fracture method to classify the
development of urban traffic in China[6], Wang, et al. use the spatial association analysis model (ESDA
method) to analyze the spatial distribution differences in the highway network in Northwest China[7].

There are many studies on the differences in regional economic development and transportation
development, and abundant literatures about the interaction between transportation and regional
economy, but few scholars analyze the interaction between transportation development differences and
economic development differences. Therefore, this paper firstly uses Gini coefficient to calculate the
spatial disequilibrium degree of China's transportation network development and economic
development, and then uses Granger causality test to explore the interaction, so as to enrich the empirical
research on the relationship between transportation and regional economy, and provide theoretical basis
for promoting the balanced development of regions in China.

2. Methodology
We evaluate the regional transportation network and economic development equilibrium based on Gini
coefficient, and Granger causality test is applied to analyze the interaction between the two differences.

2.1. Gini coefficient
Gini coefficient is an index put forward by Italian economist Gini to calculate the equality degree of
income distribution according to Lorenz curve. Later, it is also widely used to evaluate the balanced
development of regions, and become the most commonly used measurement model of relative
differences index. In this paper, the Gini coefficient is calculated by covariance method proposed by
Anand[8].

Assuming that there are \( n \) economic zones, the per capita GDP or transportation network density
are respectively \( x_1, x_2, \cdots, x_n \), and \( x_1 \leq x_2 \leq \cdots \leq x_n \), then the Gini coefficient of economic
development or transportation development is as follows.

\[
G = \frac{2 \text{cov}(X_i, i)}{nx} = \frac{1}{n} - \frac{n+1}{2x}
\]

The Gini coefficient is in \([0, 1]\), the higher the value is, the more unbalanced the spatial distribution
is.

2.2. Granger causality test
Granger causality test is a method based on VAR model proposed by Granger and extended by Sims to
test the causality among variables. The essence is to test whether the lag variable of one variable can be
introduced into other variable equations. If one variable is affected by the lag of other variables, they
are said to have Granger causality.

In this paper, Eviews9.0 software is used to test whether there is a Granger relationship between the
transportation development spatial differences and economic development spatial differences, so as to
analyze the interaction between them. Granger causality test consists of three steps: unit root test of time
series, cointegration test of single integration series of the same order and Granger causality test. The
mathematical equations are not detailed here because of the length problem.

3. Case study

3.1. Study area and data
This paper uses the provincial data of China from 1997 to 2017 for analysis. Taking 31 provincial autonomous regions of China (34 in total, excluding Taiwan Province, Hong Kong and Macao) as the basic spatial units, the country is divided into eight comprehensive economic regions, see Table 1 for details. The relative differences in transportation network and economic development in the whole country and each economic region are calculated respectively.

Table 1. Division of eight economic zones in China.

| Economic regions                      | Provinces included                                      | Code name |
|---------------------------------------|--------------------------------------------------------|-----------|
| Northeast Economic Zone               | Liaoning, Jilin, Heilongjiang                           | DB        |
| Northern Coastal Economic Zone        | Beijing, Tianjin, Hebei, Shandong                       | BY        |
| Eastern Coastal Economic Zone         | Shanghai, Jiangsu, Zhejiang                            | DY        |
| Southern Coastal Economic Zone        | Fujian, Guangdong, Hainan                              | NY        |
| The middle reaches of the Yellow River| Shaanxi, Shanxi, Henan, Inner Mongolia                 | HZ        |
| The middle reaches of the Yangtze River| Hubei, Hunan, Jiangxi, Anhui                         | CZ        |
| Southwest Economic Zone              | Yunnan, Guizhou, Sichuan, Chongqing, Guangxi           | XN        |
| Northwest Economic Zone               | Gansu, Qinghai, Ningxia, Tibet, Xinjiang               | XB        |

Most studies only focus on one kind of transportation network, which is not representative enough. In this paper, we choose the railway and highway construction of 31 provinces to analyze the non-equilibrium of transportation network in China. The reason why inland waterway and pipeline data are not included is that these transportation routes are greatly affected by geographical location and resource conditions, and therefore have little significance for the study of equilibrium. Aviation network data is not included because provincial route data is not available.

The density of highway/railway network and per capita GDP are respectively used to measure the transportation network and economic development level of each region, and the relevant statistical values are from China Statistical Yearbook. It is worth noting that the GDP value published at the current year's price has been deflated using 1995 as the base period.

3.2. Calculation and analysis of Gini coefficient
The change curves of Gini coefficients of railway and highway development and economic development in China from 1997 to 2017 is shown in Figure 1. During the calculation period, the Gini coefficient of national railway and highway is in the range of 0.25-0.35, indicating that the development of national railway and highway construction is relatively fair from the perspective of network density. The distribution of railway and highway network is the most balanced in the Southern Coastal area and the middle reaches of the Yangtze River. However, in recent years, the Gini coefficient of highway network density in the middle reaches of the Yangtze River area has increased, which needs attention. Either for railway or highway network, the Gini coefficient of the Northwest Economic Zone is the largest, especially the Gini coefficient of the railway network, which has been kept above 0.4 in the calculation period, or even exceeded 0.5 in most periods. The gap between provinces is wide so that the Northwest is the key area for the formulation and implementation of the future balanced development strategy.

The Gini coefficient of national per capita GDP is less than 0.3 in the calculation period, which is not high by standard, but per capita GDP could not fully reflect the regional economic development differences. The regional per capita GDP differences is much lower than the regional economic development differences. The economic differences among regions are higher than those within
economic zones. The differences in provinces in the Eastern Coastal Economic Zone have improved significantly in the calculation period, while the internal provinces in the middle reaches of the Yellow River and the Southwest have increased significantly, which needs to be paid attention to by relevant departments.

Figure 1. The change curves of Gini coefficient of railway line density (a), highway line density (b) and per capita GDP (c) in China's economic regions from 1997 to 2017.

3.3. Granger causality analysis
Using eviews9.0 software, Granger causality test based on VAR is carried out between the non-equilibrium of railway/highway network (code TL/GL in this paper) development and economic (code GDP) development between 1997 and 2017 in China.

3.3.1 Stability test of variables. Econometrics requires that the time series of Granger causality test must be stable, otherwise there will be problems such as "false regression" or "false causality". Using Eviews9.0 to test the stationarity of all Gini coefficient time series, we get the stable series as $G_{TL-NY}$, $G_{TL-CZ}$, $G_{GDP-BY}$ and $G_{GDP-XN}$, the second-order single integer series as $G_{GDP-HZ}$ and $G_{GDP-CZ}$, and the rest first-order single integer series at the 5% confidence level.

3.3.2 Cointegration test. There may be some kind of stable linear combination between the single integer sequences of the same order, which reflects the long-term stable relationship between variables, i.e. cointegration relationship. The Granger causality test can only be performed between the same order single integer sequences with cointegration. If the sequence is not of the same order, it means there is no causality. Johansson cointegration test is carried out for the same order single integration sequence of Gini coefficient of railway/highway network and Gini coefficient of GDP per capita, and the VAR model between the estimated variables is used to verify the correctness of the cointegration relationship.
If all root modules of the estimated VAR model are less than 1, then the VAR model satisfies the stability condition and the cointegration relationship between variables is correct.

The experimental results show that there is a long-term stable relationship between the railway distribution non-equilibrium and economic non-equilibrium in the Northwest Economic Zone. Among the eight economic regions and in the Eastern Coastal, the Southern Coastal as well as the Northwest economic zones, the highway distribution differences has a long-term balanced development with economic differences. It is found that there is no cointegration relationship between the railway and highway distribution disequilibrium and economic disequilibrium in the Northeast Economic Zone because of the unstable established VAR model. There is also no long-term stable relationship between the spatial differences of railway development and economic development in the eastern coastal economic region and the whole country. In addition, the Gini coefficient series of railway/highway in other regions are not of the same integer order with the economic Gini coefficient of the region, so it can be determined that there is no relative causal relationship in these areas.

3.3.3 Granger causality test results. Granger causality test has been carried out for the single integer sequences of the same order with cointegration and stable VAR model, and the direction of interaction between variables has been determined. The lag order of Granger causality test is determined according to AIC and SC minimum criteria. The inspection results are shown in Table 2.

| Causal relationship | Lags | Pro. | Conclusion |
|---------------------|------|------|------------|
| TL-XB→GDP-XB        | 4    | 0.2595 | ×          |
| GDP-XB→TL-XB        | 4    | 0.0428 | √          |

| Causal relationship | Lags | Pro. | Conclusion |
|---------------------|------|------|------------|
| GL-all→GDP-all      | 4    | 0.0048 | √          |
| GDP-all→GL-all      | 4    | 0.0773 | √          |
| GL-DY→GDP-DY        | 4    | 0.0360 | √          |
| GDP-DY→GL-DY        | 4    | 0.7220 | ×          |
| GL-NY→GDP-NY        | 4    | 0.0177 | √          |
| GDP-NY→GL-NY        | 4    | 0.2856 | ×          |
| GL-XB→GDP-XB        | 1    | 0.9284 | ×          |
| GDP-XB→GL-XB        | 1    | 0.6281 | ×          |

At the 5% confidence level, the equality of per capita GDP level in the Northwest Economic Zone is the Granger cause of the equality of railway density; the Gini coefficient of highway density in the Eastern Coastal and Southern Coastal economic zones is the Granger cause of the Gini coefficient of per capita GDP; at the 1% confidence level, the spatial differences of highway density among the eight economic zones is the Granger cause of the differences of per capita GDP and it becomes a bidirectional causality at the 10% confidence level. All of the above are valid in the case of 4 lagging sections. Although there is a cointegration relationship between the highway density equality and the economic level equality in the Northwest Economic Zone under the first order lag, it fails to pass the Granger causality test.

4. Conclusions
This paper analyzes the regional spatial differences in transportation network (railway, highway) development and economic development in eight economic regions of China and the possible Granger causality between them, and obtains some valuable conclusions. First of all, as far as the whole country is concerned, there are obvious spatial differences and significant imbalances in the development of railways, highways and economic in the eight economic regions of China, among which the differences in the highways’ development are the greatest. The differences in the economic development among
economic regions are higher than the differences within each economic region. Secondly, as far as the economic zones are concerned, the Northwest Economic Zone and the middle reaches of the Yangtze River Economic Zone are the regions with the greatest disparity and the most balanced transportation development respectively. The differences in highway density among provinces in the middle reaches of the Yangtze River Economic Zone and the differences in economic development of provinces in the middle reaches of the Yellow River and the Southwest Economic Zone have an expanding trend, which should be paid attention to by relevant departments.

Through the test and analysis of the cointegration and causality between the Gini coefficient series of regional transportation and economic development, this paper holds that there is no long-term stable relationship between transportation development differences and economic development differences in most economic regions. The disequilibrium of transportation development and economic development in various provinces are more affected by other factors, while some of the economic regions have been proved to have a correlation between them. For example, in the long run, the highway development differences in the Eastern Coastal Economic Zone will aggravate the economic development differences among the provinces, while that in the Southern Coastal Economic Zone will help the economic development of the provinces to be more balanced. And the economic development differences in the Northwest Economic Zone will make the distribution of railways in the economic zone more uneven. There is a bidirectional Granger causality between the road development differences and the economic development differences among the eight economic regions in China. Therefore, there is an interactive relationship between the road development balance and the economic development balance in China. Furthermore, this paper holds that the future regional balanced development strategy in China should pay attention to the possible impact of the road network construction on the economic development gap.

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