The correlation between GDP and different transport modes turnover based on grey correlation analysis

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Abstract. Transportation is the inherent law of economic development. With the deepening of reform and opening up, the adjustment of economic and industrial structure, transport volume have driven GDP growth to varying degrees. Therefore, based on the 1990-2017 transport turnover and GDP in China, this paper studies the decoupling relationship between GDP and transport volume at different stages, in which traffic volume has a week decoupling with GDP. By using the grey correlation analysis, the degree of correlation between different freight and passenger transportation modes at sample period is calculated to demonstrate the similarity with economic growth.

1. Introduction

Transportation development is the driving force of the national economy. After the implementation of five five-year plans, China's economy grew rapidly from 1990 to 2017. GDP increased from 1887.29 billion Yuan to 82,712.17 billion Yuan, an increase of 42.8 times, and the compound annual growth rate reached 15.03%. Meanwhile, freight turnover has increased by 6.53 times and passenger traffic has increased by 4.83 times. With the deepening of reform and opening-up policies in China, the adjustment of economy and industrial structure, freight traffic and passenger traffic have driven GDP growth respectively.

Numerous studies find the same tends between transport volume and GDP [1-3]. Lean etc. use Granger cause method implies that the economic development causes more demand for logistic service and then increase the traffic volume, and railway plays an important role in transport network by improving the traffic of road and waterway [4]. And the improvement of transportation can improve productivity, erase technology spillover and reduce costs of products [5]. Maparu and Mazumder explore the causal relationship between economic development, transportation facilities and urbanization development, by using the cointegration and Granger causality test for empirical analysis in India. Though different empirical methods have inconsistent results, mutual promotion between different modes of transport and economic development has been proven [6]. Therefore, the mutual effect between traffic volume and economic growth is estimated, determining the causality is difficult.

But less attention is paid to the relationship between passenger turnover of different modes and GDP. With the continuous construction and improvement of the transportation network, the quantity and quality of passenger transportation are constantly reducing travel time and meeting the needs of users. Therefore, we should further study the relationship between passenger turnover and GDP. Moreover, the existing research also pays less attention to the influence of different modes of transportation on GDP growth. The organization of this paper is as follows. Section2 describes the dataset in sample period, and the development tendency of different transport modes in freight and passenger turnover. Section3 uses the methodology to empirically study the decoupling between GDP and transport turnover,
then analyse the correlation index among different transport modes with GDP by grey correlation analysis. Section 4 discusses the empirical result and conclusion.

2. Panel data
The dataset was obtained from the National Bureau of Statistics of China (NBS) from 1990 to 2017. In the study of freight turnover, the ocean shipping turnover is removed to eliminate the impact of international trade.

2.1 Freight turnover
The freight turnover of railway transportation has been steadily increasing year by year especially in 2007, but has stabilized slightly downward recently due to reduction of bulk goods. The freight turnover of road transportation has increased significantly in 2008. According to the data of the statistical yearbook, the adjustment of the statistics of road transportation in 2008 is the cause of the sudden change in the turnover of roads. Inland water transport growth is stable. Although the proportion of pipeline transportation and air transportation has been small, the total amount is increasing.

2.2 Passenger turnover
From 1990 to 2017, the total amount of passenger traffic increased year by year, except the sharp decreasing in 2013. And the rapid decline of road passenger turnover in 2013 led to a decline in total passenger traffic. According to the data of the statistical yearbook, the statistical caliber of road traffic volume was adjusted in 2013. If calculated by comparable caliber, road passenger turnover would increase by 1.0% year-on-year. The turnover of conventional rail and civil aviation has been steadily increasing in sample period. After the operation of High Speed Rail in 2008, the turnover of HSR increases sharply with compound annual growth rate 93.29%. The proportion of waterway turnover has been low, and has dropped from the initial 2.93% to 0.23%.

3. Methodology

3.1 Decoupling analysis
The Decoupling method is widely used in the relationship among economic growth, traffic volume and environmental conditions. Tapio used the concept of decoupling, which is expressed as the percent change of transport volume is divided by the percentage change of GDP in a given time period [1]. And also redefines the decoupling analysis and divides the decoupling into 8 statuses based on the values of ΔVOL, ΔGDP and decoupling. Table 1 shows the 8 decoupling statuses.

| Decoupling status | D | ΔVOL | ΔGDP |
|------------------|---|------|------|

Figure 1. Freight turnover of different transport modes (billion ton-km)  
Figure 2. Passenger turnover of different transport modes (billion p-km)
Week decoupling | 0-0.8 | >0 | >0
Expansive coupling | 0.8-1.2 | >0 | >0
Expansive strong coupling | >1.2 | >0 | >0
Strong negative decoupling | <0 | >0 | <0
Week negative decoupling | 0-0.8 | <0 | <0
Recessive coupling | 0.8-1.2 | <0 | <0
Recessive decoupling | >1.2 | <0 | <0
Strong decoupling | <0 | <0 | >0

To normalize the GDP, freight and passenger turnover of sample period, the data of 1995 is set as 100. Because the GDP in sample period is increasing year by year, that is, the value of ΔGDP is all positive, and the traffic volume data is basically increasing year by year, except for the declining trend in individual years. Therefore, the decoupling values are mainly in the three states of week decoupling, expansive decoupling and strong decoupling. As can be seen from Figure 3, in most years, the degree of decoupling is 0-0.8, which is the week decoupling, that is, the increase pace of freight and passenger turnover is obviously smaller than GDP.

Figure 3. The decoupling relationship between turnover and GDP

The decoupling value in the year of 0.8-1.2 indicates the degree of increase in freight and passenger turnover is approximately equal with GDP. And the year in which the decoupling value is greater than 1.2 indicates that the increase pace of freight and passenger turnover is obviously larger than GDP. The negative decoupling value means that although the economy grows, the traffic volume tends to decline, which is strong decoupling. Therefore, the growth rate of GDP is significantly faster than the increase in freight and passenger turnover in sample time period. In 2013, the degree of decoupling between the passenger turnover and GDP was the largest due to the adjustment of statistic yearbook.

3.2 Grey correlation analysis
Grey Correlation Analysis is a branch of the grey system theory. It is based on the similarity or dissimilarity of the development trends between factors, therefore, the "grey correlation degree" as a method to measure the degree of association between factors. The meaning of grey correlation analysis is that if the two factors changes are consistent during the development of the system, it can be considered that the relationship between the two is relatively large, vice versa. Therefore, the grey correlation analysis provides a quantitative measure for a system development change situation, which is very suitable for dynamic time series state variable history analysis. The grey correlation degree can be calculated as follows.

1) Determine the evaluation object and evaluation criteria. The evaluation object in this paper is GDP, and the evaluation criteria are the turnover of different transportation modes.

2) Data standardization processing. Due to the different magnitude of the numerical values, it is necessary to perform dimensionless processing on the original data, eliminate the dimension, and convert it into a comparable data sequence. For the standardization of freight turnover, passenger turnover and GDP, this paper uses the mean transformation method to eliminate the influence of the
3) The difference sequence formula is:
\[ \Delta_0 (x_k) = \left| x_0 (k) - x_i (k) \right| \]

4) Calculate the gray correlation coefficient, the equation is described as follows.
\[ x_{0i} (k) = \min \left\{ \frac{\min \left| x_0 (t) - x_i (t) \right| + \rho \max \left| x_0 (t) - x_i (t) \right|}{\left| x_0 (k) - x_i (k) \right| + \rho \max \left| x_0 (t) - x_i (t) \right|} \right\} \]

\( \rho \) is resolution coefficient and 0<\( \rho <1 \).

5) Calculate the grey weighted association.
\[ r_i = \sum_{i=1}^{n} w_i x_{0i} (k) \]

Where \( W_i \) is the weight corresponding to the i evaluation index. Usually, \( W_i \) of each vector is equal.

According to the degree of decoupling analysis, it can be judged that the freight turnover, passenger turnover and GDP growth are synchronized, so the correlation degree of different freight and passenger transportation modes to GDP can be analyzed. See the tab 2 below for a reference evaluation of the correlation statute.

| Grey correlation | Classification | Evaluation meaning |
|------------------|----------------|-------------------|
| 0.35 - 0.65      | Medium correlation | The coupling of the two system indicators is medium |
| 0.65 - 0.85      | Strong correlation | The coupling of the two system indicators is strong |
| 0.85 - 1.00      | High correlation | The coupling of the two system indicators is high |

### 3.2.1 Grey correlation of freight transportation modes.
According to the descriptive analysis and decoupling analysis of the panel data, 2008 is regarded as the demarcation point due to the adjustment of the highway statistical caliber in 2008. Then the grey correlation coefficient is used to calculate the grey correlation coefficient of different freight transportation modes.

At this stage of 1990-2007, the correlation between civil aviation and GDP growth was the highest, and the correlation between railway and GDP was 0.668, which was a strong correlation. In 2008-2017, the correlation coefficient between civil aviation, waterway, railway and GDP decreased to varying degrees, among which civil aviation decreased from high correlation (0.907) to strong correlation (0.711), and railway decreased from strong correlation to moderate correlation. The degree of correlation between road transport and GDP has increased slightly. The grey correlation coefficient of different freight transportation modes is shown in Table 3.

| Table 3. Grey correlation of different freight transportation modes |
|----------------------|-----------------|-----------------|-----------------|-----------------|
| Transport modes      | Railway         | Road            | Inland waterway | Civil aviation  |
| 1990-2007            | 0.668           | 0.715           | 0.816           | 0.907           | 0.674           |
| Conclusion           | Civil aviation > Inland waterway > Road > Pipeline > Railway |
| 2008-2017            | 0.558           | 0.741           | 0.789           | 0.711           | 0.829           |
| Conclusion           | Pipeline > Inland waterway > Road > Civil aviation > Railway |

### 3.2.2 Grey correlation of passenger transportation modes.
According to the trend of passenger turnover, 2008 and 2013 were used as demarcation points to study the correlation strength between different modes of passenger transport and GDP in the three stages of 1990-2007, 2008-2012 and 2013-2016.

In three stages, civil aviation plays an important role in GDP development and has a high grey correlation with GDP. After the operation of HSR, the impacts of improving GDP growth of HSR
increased sharply from medium correlation to high correlation with GDP. And conventional rail’s impact keep improve in third stage.

| Transport modes | Conventional rail | HSR | Road | Waterway | Civil aviation |
|-----------------|-------------------|-----|------|----------|---------------|
| 1990-2007       | 0.791             | --  | 0.831| 0.596    | 0.954         |
| Conclusion      | Civil aviation > Road > Conventional rail > Waterway |
| 2008-2012       | 0.740             | 0.480| 0.812| 0.552    | 0.942         |
| Conclusion      | Civil aviation > Road > Conventional rail > Waterway > HSR |
| 2013-2017       | 0.947             | 0.920| 0.950| 0.605    | 0.929         |
| Conclusion      | Road > Conventional rail > Civil aviation > HSR > Waterway |

4. Conclusion

Based on the 1990-2017 freight turnover, passenger turnover and GDP data, this paper uses the decoupling analysis and grey correlation analysis method to study the decoupling degree of different freight and passenger transportation modes to GDP at different stages. The specific conclusions are as follows.

In terms of rail freight transportation, the relationship between railway and GDP is still low in freight transport. In recent years, the railway freight turnover has been slowly reduced due to the reduction in bulk cargo traffic, such as coal. However, in terms of passenger transportation, the degree of railway-to-GDP linkage has increased rapidly, especially for HSR. The main reason is that in 2013, HSR entered a state of full operation, basically completed the construction of “four vertical and four horizontal”, and further proposed the development of the “eight vertical and eight horizontal” strategy. The advantages of HSR, lower energy consumption, higher safety and better comfort make the HSR develop rapidly as soon as it appearing which has impacted road and civil aviation transportation.

The correlation between road transport and GDP increased slightly, from 0.715 in the first phase to 0.741 in the second phase. Road still occupies a large share of the freight sector and is an important transportation for freight. In passenger traffic, the operation of HSR affects all other modes which slightly drop in grey correlation in 2008-2012. Nevertheless, all four passenger modes expect waterway have a high correlation with GDP in 2013-2017, because of the higher mobility of goods and population.

The decoupling between civil aviation and GDP has dropped, and this change is more pronounced in freight transport. This may be related to the sensitivity of civil aviation to economic development. In a period of rapid economic growth, civil aviation is more sensitive to economic development, will also show rapid development. When the economic growth rate slows down, the development speed of civil aviation will also slow down, so the degree of impact on GDP will be weakened.

The decoupling degree and correlation with GDP would provide a wider view for development of modal shift.

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