Research on the impact of infrastructure network on urban development

Meixia Zhang\textsuperscript{1a}
\textsuperscript{1}College of Economics and Management, Southwest University, Chongqing, China
\textsuperscript{a}swuzmx@email.swu.edu.cn

Abstract: Infrastructure network is a fundamental factor of city size and urban expansion. The successful experience of many cities shows that increasing investment in infrastructure construction has significantly improved the speed and scale of urban development. Therefore, a quantitative analysis of the impact of urban infrastructure construction on urban development can lay the foundation for sustainable development of cities. This paper adopts the data of 264 cities in China from 2006 to 2018 from the aspect of road transportation network, Internet, ecological environment and industrial structure, and uses the grey correlation model and regression analysis to study the relationship and influence between China's infrastructure and urban development.

1. Introduction
The level of infrastructure is a key indicator to measure urban development and residents' lives. Urban infrastructure refers to the material engineering facilities that provide public services for social production and residents' lives, and are used to ensure the normal progress of national or regional social and economic activities. Infrastructure construction covers multiple aspects such as transportation construction, water and electricity supply, scientific research services, commercial services, environmental protection, and sanitation. It forms the basis for the development of various activities in the city. In the current research on infrastructure and urban development, Azik Derya et al.\textsuperscript{[1]} believe that residential density, road safety, and traffic comfort are important factors that affect residents' travel, and these are closely related to government policies. Gao Pei and Lei Yu Hsiang\textsuperscript{[2]} based on the rapid development of China's telegraph network, they found that communication facilities can effectively stabilize the impact of weather and other factors on market prices and slow down economic fluctuations.

Road traffic is the basis of population movement and cargo transportation, and the good transportation network increases the feasibility and reliability of residents' travel\textsuperscript{[3]}. Road congestion and poor road conditions will increase travel time and reduce residents' willingness to travel. At the same time, the imperfect transportation increases the cost of cargo transportation, reduces the efficiency of cargo turnover, and hinders the expansion of urban scale and economic growth. As a highway for information transmission, 4G network can enable information to be exchanged and widely disseminated more quickly, thereby weakening the geography of information and expanding the spatial scope of communication\textsuperscript{[4]}. Urban greening is an important indicator for good living environment and healthy life. Urban economic growth depends on the local ecosystem to varying degrees\textsuperscript{[5]}. Environmental problems such as environmental pollution, scarcity of vegetation, and land desertification affect the living environment of human beings, and even affect social stability. Industrial structure is the foundation of economic development. Industrial manufacturing and financial
services have the characteristics of high return on capital and fast turnover. Therefore, a sound industrial structure can promote urban economic growth, expand the scale of cities, and form agglomeration effects.

Therefore, this paper comprehensively analyzes whether the urban infrastructure network has an impact on urban development from the four aspects of transportation construction, information construction, environmental protection and economic structure.

2. Data Analysis
In the urban infrastructure network constructed in this paper, four representative indicators are selected, namely, the road transportation network (traffic), the Internet (net), the ecological environment (green), and the industrial structure (stru). Considering that per capita income is an important factor to measure the economic level, it is also an important indicator of urban development potential and city size, so the per capita income of the city is selected as the dependent variable. Using the panel data of 264 cities in China from 2006 to 2018, to analyze whether infrastructure construction is beneficial to urban development, the variables are as follows (see Table 1):

| Variable | Definition | Mean | Min | Max |
|----------|------------|------|-----|-----|
| pergdp   | Per capita income | 10.17 | 4.49 | 12.86 |
| traffic  | Urban road area per capita (100 square meters) | 2.32 | -3.91 | 4.69 |
| net      | Number of Internet users (households) | 3.67 | -3.91 | 7.34 |
| green    | Urban greening rate | 3.62 | 0.00 | 5.96 |
| stru     | The proportion of the secondary and tertiary industry | 4.47 | 3.91 | 4.60 |

3. Results, analysis and discussion

3.1. Grey correlation analysis
The paper bases MATLAB to carry out the gray correlation method to analyze the correlation between the four factors and urban development. The grey correlation method makes up for the defect that the mathematical statistics method requires the data of various factors to be linearly correlated, and at the same time has the advantage of unifying the quantitative results and qualitative analysis. Then bases on STATA using regression analysis for secondary verification.

The basic idea of gray correlation is to judge the degree of closeness according to the similarity of the shape of the sequence curve. The closer the curve is, the greater the degree of correlation between the sequences, and vice versa. In gray correlation analysis, the sequence where the dependent variable (pergdp) is located is regarded as the parent sequence, and the sequence where the dependent variable is located is the subsequence:

\[ Y = \{ y(k) | k = 1, 2, \cdots, n \} \]  
\[ X_i = \{ X_i(k) | k = 1, 2, \cdots, n \} \]

In order to narrow the measurement range and simplify the calculation, firstly, the data is subjected to non-dimensional quantification processing, that is, the average value of the index is obtained, and then each element in the index is divided by the average value:

\[ x_i(k) = \frac{X_i(k)}{X_i(l)}, k = 1, 2, \cdots, n; i = 0, 1, 2, \cdots, m \]
Then by calculating the minimum difference and the maximum difference to obtain the correlation coefficient with:

$$\zeta_i(k) = \frac{\min \min \left| y(k) - x_i(k) \right| + \rho \max \max \left| y(k) - x_i(k) \right|}{\left| y(k) - x_i(k) \right| + \rho \max \max \left| y(k) - x_i(k) \right|}, \quad \rho \in (0, 1)$$

$$\Delta_i(k) = \left| y(k) - x_i(k) \right|$$

$$\zeta_i(k) = \frac{\min \min \Delta_i(k) + \rho \max \max \Delta_i(k)}{\Delta_i(k) + \rho \max \max \Delta_i(k)}$$

The gray correlation degree is:

$$r_i = \frac{1}{n} \sum_{k=1}^{n} \zeta_i(k), k = 1, 2, \ldots n$$

Value $\rho=0.5$, then $a = \min \min \Delta_i(k) = 0.000017$, $b = \max \max \left| y(k) - x_i(k) \right| = 21.073431$. According to the mean value of the gray correlation degree of each variable (see Table 2), it can be seen that the relationship between industrial structure and urban development is closer, indicating that economic conditions are the main factors affecting urban development. Industry and service industries have greatly promoted urban economic growth, bringing about phenomena such as land expansion, population migration, and industrial agglomeration. The city spontaneously expands. The second is green energy represented by the ecological environment. This result confirms the importance of sustainable development to a certain extent. Clean energy and environmental management will increase energy efficiency and improve the living environment. Those cities with a good ecological environment and high energy efficiency will gain greater development potential. The status of road traffic and Internet construction will also have an important impact on urban development, and their roles are relatively close. A good transportation network will reduce transaction costs and promote the flow of urban population and the transportation of goods. The construction of the Internet will speed up the transmission of information, realize the instant sharing of information, and reduce the cost due to information externalities, thereby improving economic efficiency and promoting urban development.

| Variable | traff | inter | green | stru |
|----------|-------|-------|-------|------|
| gamma(mean) | 0.9483 | 0.9467 | 0.9556 | 0.959 |

### 3.2. Regression analysis

Stata is a statistical analysis software whose statistical analysis capabilities far exceed SPSS and far exceed SAS in terms of computing speed. At the same time, it also has a strong programming language function, using command line to operate, but it is much simpler to use than SAS. The functions of its survival data analysis, longitudinal data (repeated measurement data) analysis and other modules even surpass SAS. Therefore, this article uses Stata to perform regression analysis to further investigate the impact of variables.

In the regression analysis of panel data, it is neither possible to simply assume that each individual has exactly the same regression equation, nor to design a separate equation for each individual, so a compromise estimation strategy is often used, that is, assuming that the individual's regression equation has The same slope, but different intercept terms can exist.

The regression equation is set as

$$y_t = x_0 \beta + z_t \delta + u_t + \epsilon_t, \quad z_t = z_t, \forall t$$

For different individuals, the two sides of the equation are averaged over time to get
\[ y_i = \bar{x}_i \beta + z_i \delta + u_i + \varepsilon_i \]  

(9)

And then perform the mean-differencing transformation to get

\[ y'_{it} = (x_{it} - \bar{x}_t) \beta + (\varepsilon_{it} - \bar{\varepsilon}_t) \]  

(10)

For the above model, sample data is brought in, and the regression results are shown in Table 3. It shows that road conditions have a significant positive effect on urban development. The more road area per capita, the better the urban traffic conditions, which makes it easier to develop cargo transportation. The increase in Internet users is also conducive to promoting economic, social, cultural and other aspects of exchanges, making up for the shortcomings of lagging road construction in some areas and long distances between cities, and enhancing the timeliness and sharing of information transmission, thereby promoting the development of the city. In the regression results, the ecological environment construction did not show a significant effect, which is quite different from the high correlation in the gray correlation analysis. The reason for this analysis may be that although the ecological environment is an important measure of the degree of urban development, it is difficult to directly transform it into the driving force of development to promote urban development and expansion. However, the regression results of industrial structure variables are consistent with the results of the gray correlation analysis above, that is, the optimization of industrial structure is helpful to urban development, and at the same time, compared with other variables, it has a greater impact on urban development. It once again shows that economic development is the foundation of urban development. The increase in the proportion of the secondary and tertiary industries in the economic structure is conducive to improving capital gains, and promoting spontaneous economic growth.

Table 3  Fixed effect regression results of panel data

|        | pergdp       |
|--------|--------------|
| traffic| 381.60***    |
|        | (29.03)      |
| net    | 47.88***     |
|        | (3.95)       |
| green  | 29.29        |
|        | (18.08)      |
| stru   | 624.79***    |
|        | (44.11)      |
| _cons  | -3.3e+04***  |
|        | (3837.15)    |
| N      | 3430         |
| R²     | 0.25         |
| Adj-R²| 0.18         |

3.3. Cluster analysis based on K-means++

In order to better identify the impact of infrastructure in different types of cities on urban development, the K-means++ algorithm is used in SPSS to cluster 264 cities. The K-means++ is highly efficient and sensitive to large sample data. The specific process is as follows:
This article clusters based on the per capita income in 2018, and applies the clustering results to the 13 years from 2006 to 2018. The clustering results show that the 264 cities are divided into two categories. The Type I cities are mostly in the southeast coast of China or the large cities in the central and western regions. These areas have relatively complete infrastructure and relatively high levels of development. The Type II cities are small cities in the eastern region and the small and medium cities in the central and western regions, which have relatively backward infrastructure construction and low levels of urbanization. Regression analysis was performed in Stata.

The results show (see Table 4) that, no matter in Type I or Type II cities, road traffic conditions and industrial structure have significantly promoted urban development, and have a greater impact in Type II cities. This may be because Type II cities have greater development potential. As an important part of infrastructure, road construction and industrial structure are still in the range of greater marginal revenue growth. Strengthening these two can significantly promote the construction of infrastructure networks. On the contrary, the Internet construction situation has a higher influence in Type I cities. The reason may be that most of the Type I cities are the southeast coastal cities. These cities are susceptible to the influence of overseas developed countries or regions. The wide application of Internet technology and information technology in the world has accelerated the economic, trade, scientific research, and cultural development of these cities with overseas countries. The exchanges in these areas have significantly affected the development speed of these areas. The classification and regression results of ecological environment in Type I and Type II cities show great differences. In Type I cities, the ecological environment, as a node of the infrastructure network, significantly promotes urban development, while in Type II cities, there is no similarity effect.

**Table 4** Regression results of two types of cities

|                 | per gdp  |
|-----------------|----------|
|                 | I        | II       |
| traffic         | 353.60***| 367.98***|
|                 | (60.94)  | (33.25)  |
|     |        |        |
|-----|--------|--------|
| **net** | 80.74*** (9.29) | 43.07*** (4.51) |
| **green** | 218.84*** (56.32) | 14.75 (20.00) |
| **stru** | 477.63*** (86.31) | 626.54*** (51.96) |
| _cons_ | -2.9e+04*** (7795.65) | -3.2e+04*** (4508.55) |
| **N** | 688 | 2742 |
| **R²** | 0.40 | 0.22 |
| **Adj-R²** | 0.10 | 0.13 |

4. Conclusion

This article measures the impact of urban infrastructure networks on urban development from four perspectives: traffic system, Internet construction, ecological environment and industrial structure. The results show that these four are closely related to urban development, and the first three have significantly promoted urban development, while the ecological environment has an impact on certain types of cities.

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