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# Triangle Law or Power Law?

## *City Size Distribution in Sub-national Levelled Administrative Areas in China*

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**Abstract:** Studies have shown that the city size distribution is in line with the power law distribution. By testing the city size distribution of cities in certain administrative levels in sub-national administrative areas in China, it was found that compared with power law distribution, the triangle law distribution put forward can better fit the city size distribution characteristics. The triangle law means the city size distribution structure is shaped like the city administrative division structure. That is, cities of the highest administrative level have far bigger size than other cities, and the city size distribution law of cities in the next administrative level is in accordance with the normal distribution. The triangle law hypothesis is put forward by the analysis of city size growth logic in China, and the institutional influence was considered as the main influencing factor. The results show that the city administrative system has probably shed light on the city size distribution. Further analysis shows the triangle law is more applicable in areas with higher population and fewer next levelled cities. Lastly, by new parameters extracted from the triangle law, the city size distribution characteristics of different regions in China are analysed.

# 1. INTRODUCTION

City size distribution is always a core topic in urban studies. This paper tests the city size distribution laws in sub-national level administrative areas in China, where cities are selected by their administrative levels. The distribution of city size takes a similar shape to the hierarchical administrative structure, and it follows the proposed triangle distribution law more closely than the power law distribution that is commonly made use of in the field of urban size distribution.

Since the beginning of the 20$^{th}$ century, China has experienced rapid urbanisation and all Chinese cities have increased in size dramatically. To bring order to the rapid spatial development, it is important to measure and evaluate the current city size distributions and make spatial plans for the future. In recent decades, the study of city size distribution in China has attracted a lot of attention from both economists and planners.

The definition and classification of cities vary, and this paper observes cities from the perspective of administrative management. In China, cities are divided into different administration levels and then given different administrative rights: some are important central cities with special economic and political policies, and some are small-sized counties or towns under the strict management of upper level local governments. This kind of hierarchical administrative division is not unique to China, but also commonly used in other countries. Chinese cities are greatly influenced by their institutions (Chan & Zhao, 2002; Fan, 1999; Wei, 2015), more so than market forces (Xiao, 2016). According to the Chinese administrative regime, administrative areas are the foundational geographical units for managerial affairs, for example, the implementation of top down policies and local regulations, as well as the allocation of financial resources and task indicators. Cities at different administrative levels have hierarchical development rights over competing resources, which most likely influences city size distribution. According to the analysis of the city administrative management system above, if the target cities are included based on the hierarchical administrative system, the distribution may be institutionally shaped. Also, the standing research of city size distribution law is varied, but very little of it has connected the hierarchical administrative management system with city size distribution law.

On the other hand, the city size distribution in sub-national level regions may result from the power law distribution, but it is still not certain. In the field of city size distribution, the Pareto law and Zipf's law (also known as Rank-size law) are the most well-known regulations, and both the Pareto law and Zipf's law are based on the power law distribution. In empirical studies, Zipf's law has been repeatedly proven in different countries (Fujita, Krugman, & Venables, 1999; Mills & Hamilton, 1994; Rosen & Resnick, 1980) to accord with the city size distribution in national units. Nevertheless, the power law distribution is theoretically a kind of non-scale distribution, so mathematically the distribution form in any subdivision of the series will be the same. Therefore, in this study, as commonly recognised, city size distribution may follow the power law distribution as well, however, some empirical studies in subnational level areas have shown that the applicable geographical areas of these laws have limited scale, so further studies should be done to discover the city size distribution law in sub-national China.

The paper is organized as follows. Firstly, the city administrative division in China is introduced. Secondly, according to the analysis of the city size growth logic and its relationship to city administrative level, a hypothesis is proposed regarding city size distribution regulations in China, called the tringle law. Thirdly, the studies on the applicable area for Pareto's law and Zipf's law are reviewed, in order to prove the limitation that there are no appropriately and universally used methods for studying subnational level city size distribution. Fourth, the city population and built-up city area data is used as the city size to test whether the city size distribution law is consistent with both Pareto's and Zipf's law, and also the triangle law. This reveals that for most of the sub-national areas, the triangle law is better at describing city size distribution. Finally, there are further findings shown, such as the socioeconomic characteristic analysis of the results and the city size distribution analysis of the triangle law.

# 2. LITERATURE REVIEW

## 2.1 City administrative divisions in China

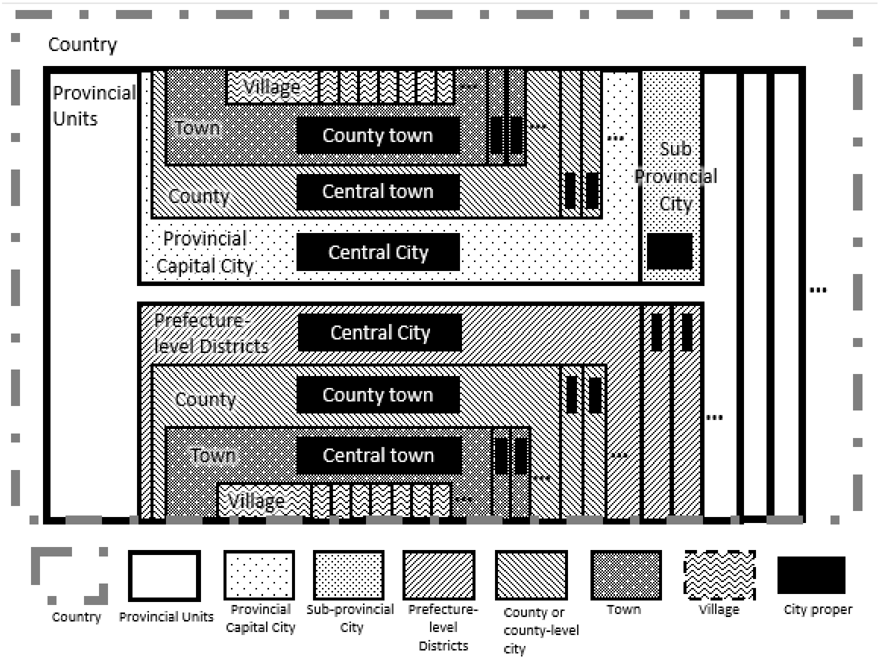



*Figure 1.* Urban administrative divisions in China

*Figure 1* shows the urban administrative divisions in China. The country is divided into several provincial units, which includes 27 provinces or autonomous regions and four municipalities. Different provinces and autonomous regions have similar city hierarchy systems. In general, each provincial unit is spatially divided into several prefecture level districts, where some are cities, others are districts, and one is the provincial capital city. In fact, the provincial capital city is not a legal city administrative level. According to the administrative system in China, 10 of the 27 provincial capital cities are more specifically sub-provincial cities. They are in a higher administrative level than prefecture-level city, although both provincial capital cities and the normal prefecture-level cities are spatially divided in the same layer, meaning they are units next to each other. More specifically, in some provinces (Shandong, Zhejiang, Fujian, Liaoning and Guangdong), there are two sub-provincial cities (where one of them must be the provincial capital city). For the other 17 of the provincial units whose capital cities are among the prefecture level cities, the residents are governed by provincial local governments, and the city has some special administrative rights and special advantages in their economic activities. Above all, the city administrative hierarchy system in China is complex. In order to simplify it, this research takes the provincial capital city (regardless of administrative level) and the sub-provincial cities as level-two cities, and prefecture level cities as the level-one cities.

In more subdivided layers, the prefecture-level cities and provincial capital cities are divided into counties or county-level cities, and then the county units are further divided into towns and the towns into villages. Each city administrative unit spatially represents two concepts: one is the city proper, which is the concentrated urbanised area (the black squares in

*Figure 1*); and the other is the administrative area of the whole region, which includes both urbanised and non-urbanised parts (the striped space in *Figure 1*). Specifically, the city proper of prefecture-level city *A* would be the administrative centre where the local government of city *A* is located. The area outside the centre of city *A*, inside region *A*, is made up of the lower county-level administrative units that are to some extent governed by city *A*. As is shown in *Figure 1*, counties or county-level cities and towns have similar urban and rural integrated structures, but their lower-level units are towns or villages. Cities and towns in this research refer to the city proper or the central settlement rather than the whole administrative area.

## 2.2 Hypothesis of city size distribution triangle law

Economists interpret the city size distribution from the perspective of economics and geography, supported by many famous theories, including the central place theory from Christaller, (1966), the spatial economic theory from Fujita, Krugman, & Venables, (1999), and the new classical economics from (Yang & Zhang, 2000), which relate city size distribution to the total population, the total spatial range, the transaction efficiency, division of labour, the urban function, the urban connection and so on.

However, City size distribution in China is also closely related to institutional factors (Anderson & Ge, 2005; Chan & Zhao, 2002; Fan, 1999). In the wake of the rapid urbanisation since the 1990s, China's urbanisation rate has doubled, and the population and land use size of Chinese cities has grown. After the tax sharing reform in 1994, "land development has not functioned simply as a passive outcome of urbanisation but has been actively pursued by local governments as a means of revenue generation to finance local economic growth" (Lin & Yi, 2011). What's more, economic achievement is a main factor in the promotion of local government officials, so land development rights that are managed through different kinds of spatial planning have become a very competitive indicator for local governments. Local government at different administrative levels have different rights in competing for the development resources; for example, some urban plans made by governments in lower levels must be approved by higher government bodies; on the other hand, the land use plan in lower level cities is mainly decided by the branch of Ministry of Land and Resources in higher level administrative units. As a result, the city proper in higher level administrative areas has better land development opportunities, while inside the whole administrative area, central cities in the lower administrative areas have poorer but similar land development needs. These institutional factors influence the city land use size distribution. The imbalance of resource allocation in different city levels also reflects certain aspects, such as the quality of public services and infrastructure, and the standard of enterprises (Wei, 2015). The differences in land development rights are similar to the differences in the population concentration for cities at different levels.

Thus, it is evident that the city land use size distribution, as well as the city population size distribution, obeys a triangle law. The triangle law hypothesises that the highest-level city in an administrative area, such as the level two cities in a provincial unit, have the biggest size, and the other lower level cities, such as the main city area of prefecture-level cities in a provincial unit, have similar sizes obeying the normal distribution because they have similar political opportunities in competing for the city's growth resources and the economical and geographical factors work against them. Such structures can be described in a triangle shaped structure in *Figure 2*, where the top of the triangle represents the size of the highest-level city inside the administrative area, and the bottom line represents the size of other lower level cities. In *Figure 2*, the *y*-coordinate is the measurement of urban size, and the *x*-coordinate is the cities ranked by name.

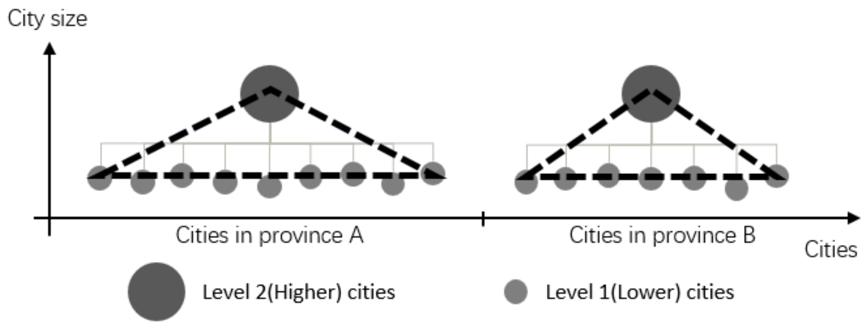



*Figure 2.* Pattern diagram of city size distribution triangle law

## 2.3 Theories of city size distribution power law

Pareto's law (Auerbach, 1913) and Zipf's law (Zipf, 1949) are two of the most commonly used theories for describing city size distribution. Though the two theories have different equations, they can transform from each other mathematically and Zipf's law is equal to when the Pareto exponent is equal to 1. Thus, Pareto's law and Zipf's law are "two different ways of looking at same things" (Adamic & Huberman, 2002). Both Pareto law and Zipf's law are based on the power law distribution.

There is a discussion in the existing research over whether the city size distribution in sub-national areas follows the power law distribution. Some studies provide positive evidence. The scale invariance is the main property of the power law distribution, which means there is a self-similarity agglomeration regulation existing across many spatial levels, and the size distributions in small areas are similar to those in large areas (Batty, 2008). Furthermore, Giesen & Südekum, (2011) have proven through empirical research that Zipf's law can be used at not only the national level, but also for subnational administrative areas and random selected areas, however, the actual situation and the theoretical assumptions are not always exactly the same. The research of Giesen and Südekum has some limitations in answering this question because they used the Pareto exponent at different area scales without testing whether the power law distribution is suitable for the city size distribution. Their research is mainly concerned with whether to reject the hypothesis that the Pareto exponent equals 1. However, if the series is not a power law distribution, it can also be used to estimate the Pareto exponent, so their research is mainly useful in demonstrating that city size distributions at different scales have similar degrees of dispersion. Such fear is warranted because, recently, scholars have found that log-normal distributions or double Pareto distributions, instead of power law distributions, can provide better approximations of the empirical urban size distribution in China by comparison to statistical methods (Anderson & Ge, 2005; Deng & Fan, 2016). Also, according to Schaffar & Michel Dimou, (2012), whether the city size distribution belongs to Zipf's law is largely determined by a study's definition of city and its research area. Furthermore, Ioannides & Skouras, (2013) found that only the upper tail of US city size distribution obeys Pareto's law robustly. There is still no research to test whether the power law distribution is applicable to subnational areas in China, especially for the cities selected at the administrative level. Because of this gap, this study necessarily includes the statistical test of power law distribution at the subnational level.

## 3. DATA AND METHODLOGY

### 3.1 Data and Study Area

Sub-national level units in this article refer to provincial units. City size distribution in other smaller administrative spatial units, such as prefecture-level cities and counties, are not considered in this paper as this research is only an exploration. Shown in *Figure 2*, level-two cities refer to the city proper of sub-provincial cities and provincial capital cities, and level-one cities are other prefecture-level cities. The city proper of the county and towns as well as other non-city prefecture-level districts are excluded. The study area includes 22 provincial units in China that have more than five prefecture-level cities; if there are too few cities, the results of the statistical test is insignificant. Thus, all four municipalities and five provincial units (Xinjiang, Xizang, Hainan, Ningxia and Qinghai) are not included, as they lack prefecture-level cities.

The data used in this research is from the China Urban Construction Statistical Yearbook 2015. For city land use size, the value is taken from 'Area of Built District', and for population size, the value is taken from 'Urban Population'. According to the yearbook, 'Area of Built District' refers to "large scale developed quarters within city jurisdiction with basic public facilities and utilities", and the urban population is the population of the urban area. In provincial cities and prefecture-level cities, the two indicators are both calculated from the city proper.

### 3.2 Methodology

The methodology of this research is shown in *Figure 3*. Both the urban population size and urban land use size data are used to do the statistical test. Firstly, for each provincial unit, the sizes of all the cities are taken into the power law test. The power law package in python is used as the tool to do the test. This is one of the most advanced tools for judging whether the data is in a long-tail distribution, and to distinguish what kind of distribution it fits best (Alstott, Bullmore, & Plenz, 2014). Secondly, the data is tested for normal distribution. The statistical analysis software SPSS can provide the Shapiro-Wilk test (s-k test) to test this. Compared with the Kolmogorov–Smirnov test, which is also packaged in SPSS and frequently used in normal distribution tests, the s-k test is better for small sample cases. It must be noted that for the normal distribution test, the provincial capital city, and the sub-provincial city, which are both from level two (see *Figure 2*) are not taken into consideration. Thirdly, according to the test results, urban size distribution can be divided into four types. If the provincial unit can pass just one test, it obeys either the power law or the triangle law, and if it passes both tests, the result obeys both laws; likewise, if it fails both tests, the result obeys neither law. Finally, the results are analysed from two perspectives: firstly, the socioeconomic characteristics of the provincial units in each results group are analysed to explore their possible impact factors to the results; second, certain parameters are proposed to analyse the city size distribution structure of the provincial units that obey the triangle law in order to describe the city size distribution in sub-national level administrative areas in China using this new theory.

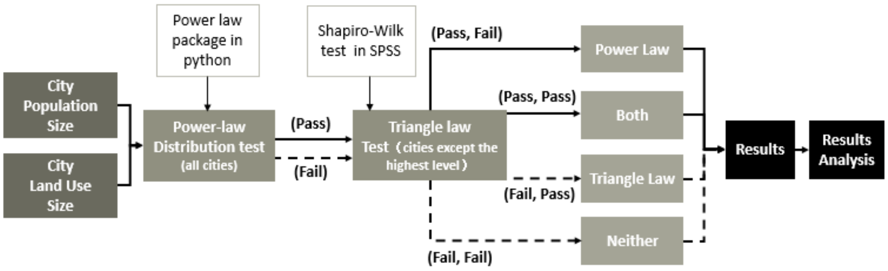
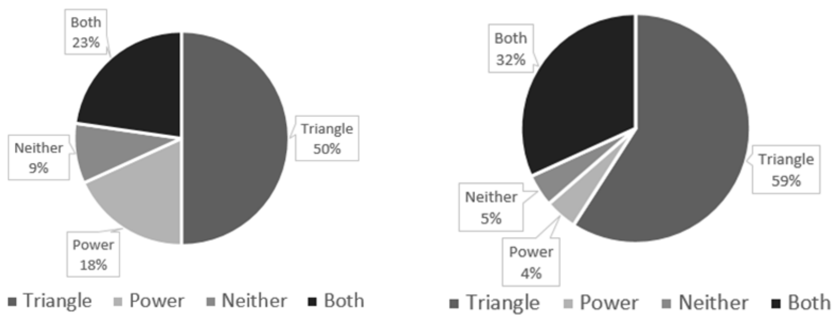



*Figure 3.* Schematic diagram of the research methodology

## 4. RESULTS

### 4.1 Overview of the results

*Table 1* and *Figure 4* are overviews of the test results: the former is the specific test results of each provincial unit, while the latter shows the proportion of each result type. Firstly, it was found that the two laws can cover most of the distribution regulations. In terms of both the land use and population size, very few of the provincial units obey neither law; most of them fit one law or both. Secondly, the triangle law hypothesis is better for describing the city population size distribution than the power law, because the triangle law can be used in most situations and is rejected in very few cases. To be specific, according to *Figure 4*, for the land use size, half of the provincial units obey the triangle law, while about one fifth of the provincial units obey both laws, and another one fifth obey the power law. For the population size, 59 percent of them obey the triangle law and one third of them obey both laws, while only one provincial unit obeys the power law. Furthermore, as shown in *Table 1*, only Guangdong province strictly obeys the power law distribution, but 10 provincial units strictly obey the triangle law on both sides. Thirdly, many of the provincial units obey both laws. *Table 1* shows that in each provincial unit, the number of normal prefecture-level cities (except for the provincial capital cities) is no more than two dozen; therefore, because of the small number of samples in each provincial unit, the proportions of the results for “both” is not inconsiderable for either perspective.




(a) Land use size distribution (b) population size distribution

*Figure 4.* Overview of the statistical test results

*Table 1.* Overview of the statistical test results

| Name of Provincial Units | Administrative Division | | City Land Use Size Distribution | | | City Population Size Distribution | | |
|---|---|---|---|---|---|---|---|---|
| | Number of Normal P-L-Cities | Number of Sub-Provincial Districts | Power-Law Distribution Test | Normal Distribution Test | Results | Power-Law Distribution Test | Normal Distribution Test | Results |
| Hebei | 10 | 10 | Fail | Pass | Triangle | Fail | Pass | Triangle |
| Shanxi | 10 | 10 | Pass | Fail | Power | Fail | Pass | Triangle |
| Neimenggu | 8 | 11 | Fail | Fail | Neither | Fail | Pass | Triangle |
| Liaoning | 13 | 13 | Fail | Pass | Triangle | Fail | Pass | Triangle |
| Jilin | 7 | 8 | Fail | Fail | Neither | Pass | Pass | Both |
| Heilongjiang | 11 | 12 | Fail | Pass | Triangle | Fail | Pass | Triangle |
| Jiangsu | 12 | 12 | Fail | Pass | Triangle | Fail | Pass | Triangle |
| Zhejiang | 10 | 10 | Fail | Pass | Triangle | Fail | Pass | Triangle |
| Anhui | 17 | 17 | Pass | Pass | Both | Fail | Pass | Triangle |
| Fujian | 8 | 8 | Fail | Pass | Triangle | Fail | Pass | Triangle |
| Jiangxi | 11 | 11 | Fail | Pass | Triangle | Fail | Pass | Triangle |
| Shandong | 16 | 16 | Fail | Fail | Triangle | Fail | Pass | Triangle |
| Henan | 16 | 16 | Pass | Fail | Power | Fail | Fail | Neither |
| Hubei | 11 | 12 | Pass | Pass | Power | Pass | Pass | Both |
| Hunan | 13 | 13 | Fail | Fail | Triangle | Pass | Pass | Both |
| Guangdong | 22 | 22 | Pass | Pass | Power | Pass | Fail | Power |
| Guangxi | 13 | 13 | Fail | Pass | Triangle | Fail | Pass | Triangle |
| Sichuan | 12 | 12 | Pass | Pass | Both | Pass | Pass | Both |
| Guizhou | 5 | 8 | Fail | Pass | Triangle | Fail | Pass | Triangle |
| Yunnan | 7 | 15 | Pass | Pass | Both | Pass | Pass | Both |
| Shaanxi | 10 | 10 | Pass | Pass | Both | Pass | Pass | Both |
| Gansu | 11 | 13 | Pass | Pass | Both | Pass | Pass | Both |

## 4.2 Socioeconomic characteristic analysis of the results

For the provincial units, the different statistical test results may be caused by their social economic characteristics. According to factors of the city size distribution in the literature review, *Table 2* summarises the social-economic characteristics of the provincial units in different result groups, taking the GDP per capita, the total population, and the number of normal prefecture-level cities into consideration, where the average value of these indexes is calculated for each group. *Table 2* shows that, on the one hand, regardless of the population or land use size, provincial units that obey the power law have bigger populations and more prefecture-level cities, but the ones that obey the triangle law are the opposite; on the other hand, the provincial units with higher average GDP per capita are more likely to obey the triangle law in terms of city land use size distribution and the power law in terms of city population distribution.

*Table 2.* Social-economic characteristic analysis of provincial units in results

| Data Type | Distribution Type | Average GDP Per Capita (yuan) | Average Total Population (1,000,000 persons) | Average Number of Normal P-L-Cities |
|---|---|---|---|---|
| Land Use Size Distribution | Power + Both | 26957.94 | 59.26 | 12.89 |
| | Triangle + Both | 27435.35 | 54.08 | 11.19 |
| Population Size Distribution | Power + Both | 26726.57 | 51.44 | 11.63 |
| | Triangle + Both | 25658.84 | 49.99 | 10.75 |

## 4.3 City size distribution analysis by triangle law

The Pareto exponent is commonly used as an index to describe the city size distribution structure, but the mathematical model of this parameter uses the power law distribution. As many of the provincial units obey the triangle law, this part focuses on these triangle law units and analyses their city size distribution structure within the parameters of the triangle law. The triangle law distribution consists of a special value (sizes of level 2 cities) and a normal distribution (sizes of level 1 cities). Certain normal distribution parameters are selected, including the average value, the standard deviation, the skewness and the kurtosis (calculated by SPSS) to describe the city sizes at level 1, and calculate the ratio of the average level 2 to level 1 city size to describe the relationship between the two levels. *Table 3* shows detailed results for each provincial unit.

Furthermore, China has a very large area and the regional differences are reflected in both economic vitality and political force; ultimately, these differences are reflected in the features of the city size distribution. The bottom of *Table 3* summarises the results by location, and divides China into four geographic regions: east, northeast, middle, and west, as shown in *Figure 4*. The east includes Hebei, Shandong, Jiangsu, Zhejiang, Fujian Guangdong; the middle includes Shanxi, Henan, Hubei, Hunan Jiangxi, Anhui; north-eastern China includes Heilongjiang, Jilin, Liaoning and Neimenggu; and the west includes Gansu, Shaanxi, Sichuan, Guizhou, Yunnan, Guangxi. Municipalities and provincial units with less than five prefecture-level cities are not included. The east is coastal with the highest level of economic development, while the west is the lowest region, and the middle and northeast are intermediate transition regions.

*Table 3* shows the results of the analysis. First, the city size distribution shows gradual regional differences. For both the land use and population size, the values of the level 2 average to the level 1 average, from the maximum to the minimum, are distributed as west, middle, northeast then east, which is the same order as the value of level 1 standard deviation. Second, the results show that the distribution structure is shaped like a heavy tail distribution, though it failed the power law test. In *Table 3*, the skewness is between 0.5 to 1, which means the right tail of the distribution is longer than the left one, and meanwhile the kurtosis results are all from 1 to 2 (bigger than 0), which means they have stronger peaks and heavier tails than a normal distribution. Third, the difference between city land use size and the population size appears mainly in two aspects, the ratio of level 1 to level 2 and the level 1 average standard deviation, while the value of the other two parameters for the same provincial units is always similar. *Table 3* shows that the land use size difference between level 2 cities and level 1 cities is smaller than that of the population size, and the standard deviation is bigger.

*Table 3.* Analysis of triangle law distribution structure

| Provincial Units | City Land Use Size | | | | City Population Size | | | |
|---|---|---|---|---|---|---|---|---|
| | Level 2 Average/ Level 1 Average | Level 1 Average Standard Deviation | Skewness | Kurtosis | Level 2 Average/ Level 1 Average | Level 1 Average Standard Deviation | Skewness | Kurtosis |
| **Hebei** | 2.38 | 61.33 | 0.69 | 1.33 | 2.79 | 51.85 | 0.69 | 1.33 |
| **Shanxi** | | | | | 5.87 | 25.88 | 0.69 | 1.33 |
| **Neimenggu** | | | | | 2.44 | 38.34 | 0.75 | 1.48 |
| **Liaoning** | 4.54 | 31.55 | 0.64 | 1.23 | 4.77 | 32.52 | 0.64 | 1.23 |
| **Jilin** | | | | | 6.18 | 30.24 | 0.79 | 1.59 |
| **Heilongjiang** | 4.27 | 61.41 | 0.66 | 1.28 | 6.52 | 28.78 | 0.66 | 1.28 |
| **Jiangsu** | 3.67 | 101.63 | 0.64 | 1.23 | 4.43 | 54.73 | 0.64 | 1.23 |
| **Zhejiang** | 3.57 | 62.75 | 0.69 | 1.33 | 3.74 | 38.31 | 0.72 | 1.4 |
| **Anhui** | 5.14 | 33.02 | 0.55 | 1.09 | 3.8 | 25.98 | 0.56 | 1.09 |
| **Fujian** | 3.84 | 56.56 | 0.79 | 1.59 | 4.18 | 25.21 | 0.79 | 1.59 |
| **Jiangxi** | 4.12 | 28.89 | 0.69 | 1.33 | 4.65 | 18.94 | 0.69 | 1.33 |
| **Shandong** | 2.91 | 62.78 | 0.58 | 1.12 | 3.1 | 38.09 | 0.6 | 1.15 |
| **Henan** | | | | | | | | |
| **Hubei** | | | | | 7.83 | 24.19 | 0.66 | 1.28 |
| **Hunan** | 3.98 | 27.35 | 0.64 | 1.23 | 5.48 | 24.35 | 0.64 | 1.23 |
| **Guangdong** | | | | | | | | |
| **Guangxi** | 4.42 | 42.97 | 0.62 | 1.19 | 5.08 | 28.88 | 0.62 | 1.19 |
| **Sichuan** | 8.15 | 27.84 | 0.55 | 1.06 | 8.36 | 24.19 | 0.55 | 1.06 |
| **Guizhou** | 5.32 | 14.57 | 0.91 | 2 | 5.08 | 15 | 0.91 | 2 |
| **Yunnan** | 12.22 | 15.1 | 0.79 | 1.59 | 14.54 | 14.89 | 0.79 | 1.59 |
| **Shaanxi** | 9.11 | 21.55 | 0.72 | 1.4 | 9.48 | 24.71 | 0.72 | 1.4 |
| **Gansu** | 7.12 | 17.48 | 0.66 | 1.28 | 6.85 | 13.64 | 0.66 | 1.28 |
| **Affiliated areas** | | | | | | | | |
| **East China** | 3.27 | 69.01 | 0.68 | 1.32 | 3.65 | 41.64 | 0.69 | 1.34 |
| **Northeast China** | 4.4 | 46.48 | 0.65 | 1.26 | 4.98 | 32.47 | 0.71 | 1.39 |
| **Middle China** | 4.41 | 29.75 | 0.63 | 1.22 | 5.53 | 23.87 | 0.65 | 1.25 |
| **West China** | 7.72 | 23.25 | 0.71 | 1.42 | 8.23 | 20.22 | 0.71 | 1.42 |
| **China** | 5.3 | 41.67 | 0.68 | 1.33 | 5.76 | 28.94 | 0.69 | 1.35 |

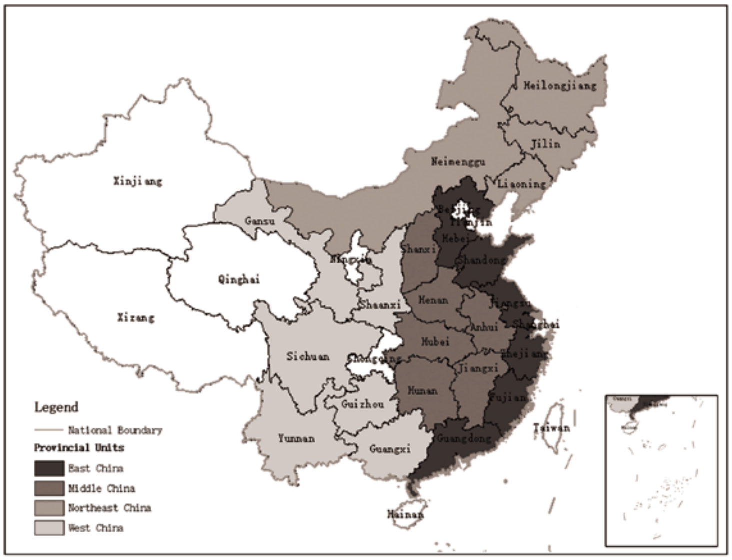



*Figure 4.* Division of geographic regions in China

# 5. DISCUSSION

## 5.1 Significances

The most significant point of this paper is the proposal of the triangle law hypothesis and the remarkable results showing that most provincial units cannot reject the triangle law hypothesis, while many of them do reject the power law distribution test. To some extent, this means that the hierarchical administrative division, together with the administrative system, financial system, and spatial planning system, have shaped the city size distribution in sub-national areas.

However, as the Pareto exponent is the most commonly used method for measuring the characteristics of city size distribution, this research cannot deny the applicability of the Pareto law and Zipf’s law. Because many provincial units obey both the power law and the triangle law, and with results showing that the city size distribution follows the triangle law, the value of skewness and kurtosis means that the normal distribution of level 1 city sizes always have a biased shape. Importantly, the new parameters from triangle law can be used to understand the urban size distribution structure; as the normal distribution is the foundation of many statistical research methods, whether or not city size distribution of level 1 cities surpass the normal distribution is significant for enabling statistical methods in further urban size studies.

## 5.2 Implications

To summarise the results above, there are many interesting implications. It is thought that the smaller the size differences of level 1 cities and the bigger the size differences between cities of the two levels, the clearer the triangle structure is. Compared with the city land use size, the city population size distribution has a clearer triangle law structure. The possible reason may be that the resource allocation factor contributes more than the spatial planning factor in shaping the city size distribution triangle law. Furthermore, areas further east, with better market forces and economic development levels, always show less clear triangle shapes. This result could mean that with the development of regional economies, the size gap between cities of different levels will be narrower, and the characteristic city size distribution of the power law will gradually appear.

## 5.3 Limitations

This research about the city size distribution in sub-national China is only a primer, admitting some limitations. For example, city size data is limited to 22 provincial units in the year 2015, and the samples are to some extent insufficient. To better prove the triangle law hypothesis in provincial units, future research should use extended time series. This research has raised some related research questions that can be explored in the future. For the further subdivided layers, for instance the prefecture-level cities and the counties, does the city size distribution have a similar triangle law? And how about in foreign countries? The secret of city size distribution has only been slightly revealed, and future work is still very much needed.

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