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Inequality, Bi-Polarization and Mobility of Urban Infrastructure Investment in China's Urban System

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Abstract: In periods of rapid urbanization, investment in urban infrastructure should not only meet the increasing demands of all urban people, but also be equally allocated between cities to achieve social equity and sustainable development. This paper aimed to conduct quantitative research on the unbalance of urban infrastructure investment between cities in China. The measurement models for inequality, bi-polarization and the mobility of urban infrastructure investment were constructed by means of the Gini coefficient, bi-polarization index and mobility function from the urban system, and an empirical study was conducted based on panel data from 2006 to 2014. The results show that: (1) The overall inequality of urban infrastructure investment in China's urban system was relatively prominent and showed a "U-shaped" change generally. (2) The inequality between different administrative levels or regional cities only partially accounted for the overall inequality of China's urban system. (3) Inequality and bi-polarization showed inconsistent performance. (4) Mobility played a positive role in reducing the inequality and bi-polarization. Based on the empirical findings and the reality of China's urban infrastructure investment and financing, targeted policy suggestions were proposed in terms of adjusting inequality and bi-polarization, innovating investment and financing mechanisms, and optimizing urban infrastructure investment strategies.

Keywords: urban infrastructure investment; inequality; bi-polarization; mobility; urban system; China

1. Introduction

Urban infrastructure is significant for human well-being and urban sustainable development [1–3]. It not only meets the needs of urban people for public goods or services, but also provides material conditions for urban economic and social activities [1,2,4,5]. Adam Smith believes that one of the important functions of the state is "to build and maintain certain public utilities and public facilities". Infrastructure is defined as the provision of basic services to industries and households [6]. In general, infrastructure can be divided into two categories: economic infrastructure and social infrastructure. Economic infrastructure is defined as the permanent constructions, equipment and facilities, as well as the services providing for the residents and economic production, which include three aspects: (1) Public utilities (power, telecommunications, piped water supply, sanitation and sewerage, solid waste collection and disposal, and piped gas); (2) Public works (roads and major dam and canal works for irrigation and drainage); (3) Other transport sectors (urban and interurban railways, urban transport, ports and waterways, and airports) [7]. Social infrastructure is defined as physical infrastructure that seeks to promote the health, education and cultural standards of the population, which has both a direct and indirect impact on the quality of life [8] and includes these dimensions: (1) Health (medical facilities, ancillary infrastructure e.g., offices, car parks, training facilities); (2) Education (schools, tertiary facilities, hostels); (3) Housing; (4) Civic and utilities; (5) Corrections and justice [9]. Although both economic and social infrastructure have their own definitions and scopes respectively, economic and social infrastructure do overlap. Sanitation, for example, would have both an economic and health impact [10] and can be considered as both economic and social infrastructure [11]. Currently, most studies on urban infrastructure mainly adopt the concept and scope of economic urban infrastructure. Therefore, when discussing urban infrastructure, this paper adopted the concept of economic urban infrastructure which includes the six industries of water supply, energy, transportation, drainage, landscaping and environmental sanitation.

Furthermore, urban infrastructure investment (UII) is the main driving force of urbanization [12–15], by the end of the 21st century, the urban population is projected to reach 90% [16], reinforcing large-scale UII in the world, especially in the developing countries such as China and India [2]. Sustainable urbanization not only needs large-scale UII overall; how to allocate UII between cities nationwide is of the same importance [5]. UII allocation mainly impacts on urban system and the basic public services between cities [13,17,18]. An urban system represents an organic integrity composed of cities with various types and scales within a certain region [19], and its scale structure and spatial distribution have far reaching impacts on economic agglomeration and social development [12,15]. Sustainable urbanization demands a coordinated urban system [15,20,21]. At the same time, the achievement of equity has already become of one of the top goals in the sustainable development of the UN's 2030 agenda [22], which requires basic public service equalization (meaning that all people have an equal opportunity of access to public services) [23]. In terms of infrastructure, despite existing different UII efficiencies, the scale of UII is inextricably associated with the level of infrastructure development in the period of rapid urbanization generally, many regions or cities lacking enough UII have a lower infrastructure development level than that of higher UII regions and cities [24–26].

Therefore, this unbalanced UII between cities results in many problems which undermines coordinated development between cities and basic public service equalization. With regard to unbalanced UII between cities, inequality, bi-polarization, and mobility are three dimensions of unbalance [27]. Inequality and bi-polarization are two specific forms of unbalance. Mobility indicates long-term changes in unbalance and shows the impact of such changes on long-term inequality and bi-polarization. As shown in Figure 1, specifically, (1) Inequality refers to the degree of average differences between different groups. Inequality of UII between cities will result in overall uncoordinated development between cities and the overall inequality of municipal public services between cities. Due to insufficient UII, many regions and cities still have a low infrastructure development level, which cannot satisfy the residents' demands for basic public services such as traffic and energy, as well as this, many regions and cities are confronting the predicaments of water pollution, garbage siege, unsafe drinking water and others [24]. Inequality of UII between cities also leads to serious inequality of municipal public services between cities, more people have flocked into big cities with higher municipal public services, causing uncoordinated urban development between cities and forming increasingly serious "big urban diseases" such as traffic congestion and environmental pollution in big cities [12]. (2) Bi-polarization refers to the differences of two groups in two poles. Bi-polarization means that the cities with the most and the least UII increase, but the middle UII cities decrease. Bi-polarization of UII between cities would lead to the bi-polarization of city development and municipal public services, which would cause many social conflicts and much confrontation between cities with the most UII and the least UII cities [27]. Calculation of bi-polarization requires first that cities are divided into two groups in two poles based on the UII scale (or scale per capita), then that the differences between the group with more UII and the group with less UII are compared. Due to the different definitions and calculations between inequality and bi-polarization, their performances are likely to be inconsistent. Many socialists argue that most social conflicts emerge owing to bi-polarization rather than overall inequality [28]. (3) Mobility represents changes of UII sequences and positions between cities in different periods. Due to the fact that inequality and bi-polarization cannot fully reflect and account for the long-term unbalance, mobility makes up the gaps. A lack of mobility will lead to the solidification in UII between cities, namely the cities with more UII always have more UII but cities with less UII still confront UII shortages, which results in long-term uncoordinated development between cities and an unbalance of municipal public services between cities.

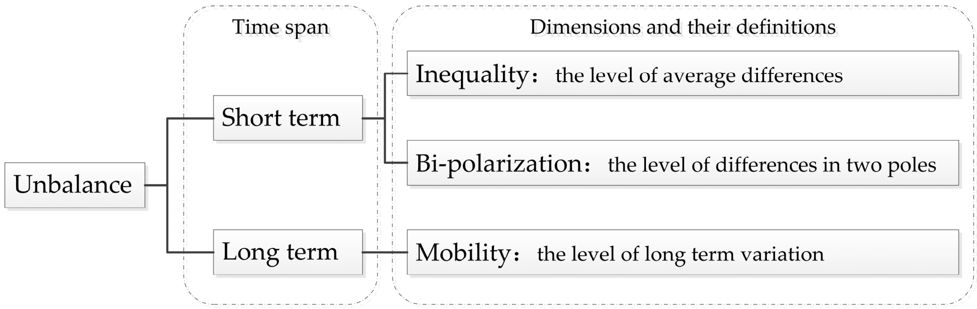

Figure 1. The logical relation between inequality, bi-polarization, and mobility.

China is now in a period of rapid urbanization [29–31], during which the number of urban people has increased from 172.45 million in 1978 to 771.16 million in 2015. Furthermore, the urbanization rate has increased from 17.90% in 1978 to 56.10% in 2015, since the implementation of reforms and the opening-up policy [32]. To satisfy the urban infrastructure demands of more urban people, as well as to promote China's urbanization, Chinese governments across all administrative levels have been constantly increasing their UII and actively exploring urban infrastructure construction mechanisms [33,34]. From 1978 to 2015, China's UII increased from RMB 1.2 billion to RMB 1.62 trillion, with an average annual growth rate (as per the comparable price) of about 25%. Additionally, the proportion of the urban gross domestic product (GDP) also rose from 0.33% to 3.11%. Such a large amount of UII not only enhances the level of urban infrastructure and strongly facilitates the rapid development of China's urbanization and industrialization, but also has a positive effect on expanding domestic demand, promoting employment and fueling economic growth [34–36].

However, local governments have gradually replaced the central government as the main supplier of urban infrastructure since China's tax-sharing system reform in 1994, and unbalances began to emerge in UII on account of regional economies and urban development policies [34,37]. Hierarchically, Chinese cities have a strict urban administrative hierarchy and cities at a higher administrative level have more available resources for infrastructure construction [38,39]. Regionally, the eastern coastal cities—which have already achieved development priority—have stronger economic strength to invest in urban infrastructure [24,40]. The unbalance of UII has seriously hindered China's urban sustainable development, such as uncoordinated urban systems and serious inequality of basic municipal services between cities or regions [12,13]. In addition, some small and medium-sized cities lacking adequate urban construction funds resort to urban infrastructure construction financing with excessive reliance on government credit, which results in serious local government debts that undermine fiscal sustainability [33].

As proposed in the Fifth Plenary Session of the 18th Central Committee of the Communist Party of China (CPC), the five development concepts of innovation, coordination, green development, opening up and sharing will be used to guide the sustainable development of China's national economy and society during the 13th Five Year Plan period (2016–2020). Among them, coordination aims to promote coordinated development across all regions and accomplish the equalization of basic public services. Starting from institution building, sharing means implementing accurate poverty alleviation and comprehensive poverty alleviation strategies, increasing government transfer payments, strengthening joint construction capacities and the sharing level of basic public services and ultimately achieving the fruits of development shared by all. Meanwhile, absolute viewpoints such as big cities, medium cities and small cities may be biased, according to related research and China's urbanization blueprint, the National New Urbanization Planning (2014–2020). The realization of coordinated urban systems and the accomplishment of equal basic public services between cities have gradually become mainstream thoughts among Chinese policy makers and theorists [13,15,20].

To realize coordinated urban systems and accomplish equal basic public services in China, some problems of unbalanced UII must be confronted: What is the level of UII inequality in China? What are the changing trends in recent years? What are the impacts of administrative levels or regions on inequality? Is there bi-polarization of UII? In a certain period of time, does the UII flow to cities of different types in accordance with a fixed structure? What is the mobility level? How does mobility impact on inequality or bi-polarization? The clarification of these issues will help to comprehensively, systematically and deeply understand the current situation and trends of China's UII unbalance, as well as provide references for China's new-type urbanization and UII mechanism reform. Furthermore, this research was also conducive to developing more systematic and targeted policies for UII allocation, realizing China's coordinated development, and achieving the equalization of municipal public services. Based on this, it is of great realistic significance to study the inequality, bi-polarization, and mobility of UII in China.

Unbalanced UII is a serious issue that the Chinese government and people are facing and trying to solve, as well as a topic of wide concern in academic circles. Existing research has mainly focused on China's UII unbalance from three aspects. (1) Measuring and comparing China's UII unbalance. There is a serious UII inequality between regions, whether total or per capita, which has the strong spatial characteristics of China's UII [36]. UII in the eastern region is far higher than that in the central and western regions, but the growth rate in the central and western regions is higher than that of the eastern region [24,26]. (2) The analysis of the reasons for China's UII unbalance from the perspectives of administrative powers and financial capacity. The distribution and redistribution of public resources are determined by the administrative levels of the various cities, and cities at higher administrative levels have more available resources for UII, leading to an unbalance between cities of different administrative levels [12,13,33,39,41]. At the same time, compared with those in backward regions, cities in developed regions have more funds for UII, causing unbalance between cities of different regions [34]. (3) Analyzing the unbalanced UII results, the level of urban infrastructure development in the eastern region is higher than that in the central and western regions, in addition, the higher administrative level cities have higher urban infrastructure development levels in general [24,26,36].

These studies not only provide a good analytical paradigm for exploring the unbalance of China's UII, but also offer many basic data for solving it, which contribute to the understanding of the current situation and trends in China's UII unbalance. However, the previous studies contain some limitations: (1) There is a lack of scientific statistics and measurements for UII unbalance; (2) Many studies just analyze the UII unbalance from the provincial level and above, or compare the UII differences between certain cities, so there is still a lack of analysis from the urban system perspective; (3) Most studies of UII unbalance only take inequality or differentia into account, but they rarely explore bi-polarization and mobility.

To combat the shortcomings of previous studies, this paper conducted further research on the inequality, bi-polarization and mobility of UII in China's urban system by: (1) Measuring the inequality of UII in China's urban system (overall inequality) and analyzing its trends in recent years; In general, China's urban system should contain all Chinese cities, including county-level cities, prefecture-level cities, sub-provincial cities, and centrally-administered municipalities according to administrative levels. To comprehensively and systematically study UII unbalance, cities at all administrative levels are included in China's urban system in this paper. (2) Classifying Chinese cities into different types according to administrative levels or regions and analyzing UII inequality within each type of city and between different types of cities, as well as their corresponding contributions to the overall inequality. (3) Exploring the bi-polarization of UII. (4) Calculating the level of mobility and analyzing the impact of mobility on inequality and bi-polarization.

The rest of this paper contains these parts: Section 2 is theoretical conceptualization and methodological framework. Section 3 introduces research materials and methods, including indicators and data, and methods. Section 4 carries out the analysis of empirical results. Section 5 provides discussion and policy suggestions. Section 6 draws final conclusions.

2. Theoretical Conceptualization and Methodological Framework

2.1. Conceptual Framework

Sustainable development is usually defined as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" [42], in which human being's needs and equity are emphasized [23]. In fact, sustainable development requires coordinated development of economics, society, and the environment [2,43,44]. As a result, urban infrastructure has been given particular attention as it not only meets urban human needs, but also has a significant impact on the economy, society and environment [2,5,10,45]. In terms of equity—which as the basis of social sustainability is one of the top goals in the sustainable development of the UN's 2030 agenda—inequality, bi-polarization, and a lack of mobility are all threats to equity and sustainable development [27]. Hence, detailed analysis of the relationship between urban sustainability and urban infrastructure will be conducted, and a conceptual framework of the relationship between inequality, bi-polarization, equity, and urban sustainability will be given in the following.

2.1.1. The Relationship between Urban Infrastructure and Urban Sustainability

Urban infrastructure is the basic condition for the development of cities, as well as being the material carrier for the provision of public services. Investment in and the construction of urban infrastructure not only promotes urban economic and social development, but also plays a crucial role in improving the quality of life of urban residents and urban environmental improvement. (1) Economically, urban infrastructure shows its significance from three aspects, which are the direct stimulation of economic development, the promotion of economic efficiency, and helping the reduction of transaction costs. The World Bank has pointed out that every increase of 1% in infrastructure stock would increase 1% of the total social output [7]. Meanwhile, urban infrastructure could improve the investment environment, and promote total factor productivity through the "spillover effect" and "network effect" [46–49]. In addition, infrastructure could reduce the transaction costs, such as transport facilities reducing the costs of transportation [50]. Infrastructure also helps specialty division and economic agglomeration, which are conducive to urban economic development [51–53]. (2) Socially, first of all, urban infrastructure has improved the level of residents' welfare. For instance, water supply facilities improve water quality that helps to reduce the incidence of diseases owing to unsafe water [54]; The improvement of transportation facilities reduces commuting costs and enhances the traffic accessibility of medical, education, sports and public green spaces, which contributes to the enhancement of residents' health, environment and education levels [55,56]. Secondly, infrastructure is currently important in order to alleviate poverty and inequality. As social overhead capital, infrastructure is considered to be the basic condition for economic and social development [35]. For the poor regions, where the infrastructure is weak, their economic and social development is limited. Infrastructure investment and construction could increase income and jobs in poor areas in the short term and could theoretically create the conditions for the further development of the economy and society in poor areas [36]. Many practices have demonstrated that infrastructure plays a positive role on inequality and poverty reduction worldwide [57–59]. (3) Environmentally, there is a continuous further consideration of the environmental effect of urban infrastructure. At first, the environmental function of green and environmental infrastructure such as sewerage treatment facilities, waste disposal facilities, and urban green spaces is merely acknowledged [60]. Thereafter, the indirect environmental significance of some urban infrastructure is recognized gradually. For instance, public transportation infrastructure is of positive significance in order to reduce energy consumption and pollution [61]; clean energy facilities can effectively replace other high polluting energy uses to reduce pollution [62].

Sustainable development requires the coordinated development of the economy, society, and environment, in addition, the ultimate goal of sustainable development is to enhance human well-being [40]. Based on the functions and impacts of infrastructure on the economy, society, environment, and human welfare, infrastructure development has become Goal 9 (build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation) in the UN's 2030 agenda [22].

2.1.2. The Relationship between Inequality, Bi-Polarization, Equity, and Urban Sustainability

Equity has been a fundamental issue for human society and a major concern of governments worldwide [63]. Indeed, equity is an important factor to promote sustainable development, which can enhance the resilience of the economy [64], promote social harmony and stability [65], as well as protect environment [66] and biodiversity [67]. Furthermore, residents living in more equitable regions have better health and a longer life expectancy [68,69].

However, there are some inequitable problems damaging social stability and undermining sustainable development. (1) Inequality is the most common unbalance issue and stands for the degree of average difference between different groups. Economically, inequality is an obstacle to sustainable growth [70–72], socially, it undermines social stability [73], politically, it depresses popular participation in public benefit activities [74], environmentally, it encourages poor people to overuse natural resources, which results in serious pollution and biodiversity loss [75]. (2) Bi-polarization represents the differences between two groups in two poles. Compared with inequality, bi-polarization more easily causes many social conflicts and much confrontation [27,28]. Analyzing the factors contributing to conflict is a key step in avoiding and controlling conflicts [76], hence, it is significant to study bi-polarization which could result in conflicts and undermine social sustainability. Besides, based on the analysis in Section 1, a lack of mobility means more serious inequality and bi-polarization over long periods, thus a lack of mobility is also a large challenge to sustainable development.

Equity requires all people have equal opportunities of development and access to the basic needs related to the quality of human life [23]. Given that urban infrastructure is the basis of urban development and the material carrier of urban public services, its balanced distribution is considered to result in coordinated urban development and basic public services between cities nationwide [5,77]. In this period of rapid urbanization, when UII is accelerating, equal or balanced allocation of UII is significant for coordinated urban development and basic public services between cities nationwide. Reversely, UII inequality, bi-polarization, or the lack of mobility would undermine sustainable urbanization and urban sustainability nationwide.

2.2. Methodological Framework

Based on the research objectives and contents, this article will bring China's urban system into the analytical framework and study UII unbalance from the dimensions of inequality, bi-polarization and mobility. Furthermore, according to a city's type of administrative level or region, this paper will explore UII inequality within each type of city and between different types of cities, as well as their contributions to the overall inequality, respectively. In addition, the impact of UII mobility on inequality and bi-polarization is also studied. As shown in Figure 2, the methodological framework is established as follows: (1) Firstly, quantifying the level and trend of UII unbalance as the research foundation and the objectives to conduct the analysis. (2) Secondly, setting up three dimensions of inequality and bi-polarization and mobility to explore. (3) Finally, exploring the specific contents based on the respective analysis perspective. It is expected that this paper will provide a proper analytical framework and paradigm for exploring unbalance of UII, as well obtaining more accurate conclusions and scientific policy suggestions to guide the relevant practice through the qualitative and quantitative study.

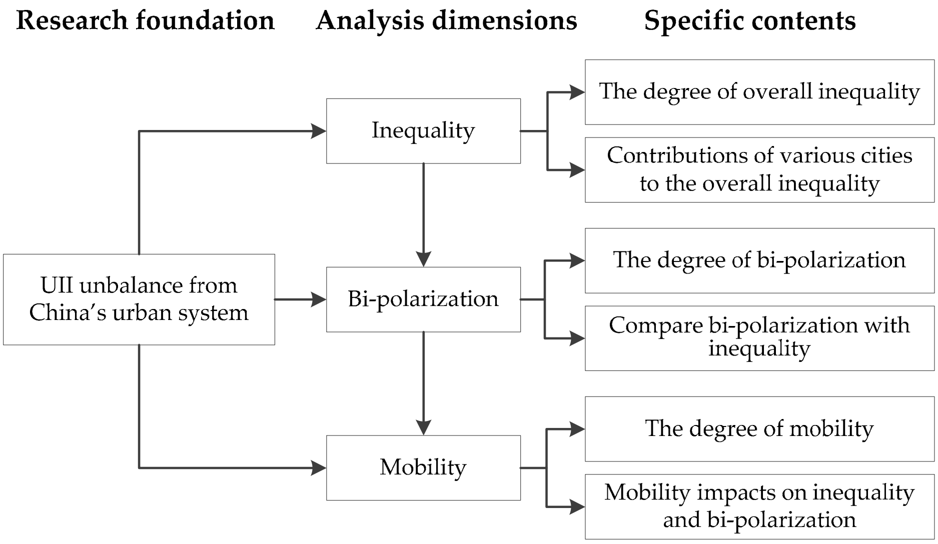

Figure 2. The logical relation between inequality, bi-polarization, and mobility.

3. Materials and Methods

3.1. Indicators and Data

A city has a distinct scale and size, and the number of urban people can better reflect a city's demands for urban infrastructure. Meanwhile, when referring to the relevant research in references [24,36,37,78], this study selected per capita urban infrastructure investment as a comparative indicator. In addition, China's urban population can be divided into an urban household (hukou) population and an urban temporary population. To fully reflect the real demands of urban people for urban infrastructure, this paper adopted the number of all urban people as the sum of the household population and the urban temporary population.

Data on the number of all urban people and urban infrastructure investments were acquired from the China Urban Construction Statistical Yearbook (2006–2014), and part of the data missing from this came from the China City Statistical Yearbook of the corresponding year.

3.2. Methods

The Gini coefficient (GC), the Theil index, and the coefficient of variation are all popular measurement methods of inequality. Among them, the GC is applied most widely [79], and it is also the foundation of many measurement methods of bi-polarization and inequality [27,80]. Furthermore, the GC can not only measure overall inequality directly, but can also be decomposed according to types of cities to find the inequality within each group and between groups, as well as their corresponding contribution rate (CR) to overall inequality [23]. Based on the above analyses, the GC was selected as the method for this study, and the measurement models were thus formulated.

3.2.1. Measuring Inequality

In light of the idea of the GC, the GC of UII in China's urban system was formulated, which represented the overall inequality of UII in China's urban system. The specific calculation formula is as follows [81]:

$$G = \frac{1}{2n^2\mu}\sum_i\sum_j\left|I_i - I_j\right| \tag{1}$$

In Equation (1), G represents GC; n represents the number of Chinese cities; μ stands for average of per capita UII; and I_i and I_j represent per capita UII of City i and City j, respectively. GC stands for the inequality of UII, and the larger the GC, the more serious the inequality.

3.2.2. Decomposing the Overall Inequality According to Various Cities

In this study, Chinese cities were classified into groups according to administrative levels or regions, and then the overall GC was decomposed in light of the groups to obtain the inequality within each group and between groups, as well as their corresponding CR to overall inequality. There are some controversies about group decomposition of GC in academic circles. In the early years, some scholars believed that the GC consisted of two parts, namely, the GC within each group and the GC between groups [82,83]. However, Das and Parikh argued that the value of GC decomposition was dependent on its economic interpretation, and two parts of decomposition were not a real statistical decomposition [84]. Following this, GC was decomposed into three parts by Mookherjee and Shorrocks, adding a possible cross besides the previous two parts that resulted from the overlapping between groups, which equaled zero if there was no overlapping between groups [85]. Nowadays, scholars generally accept the decomposition method of three parts [27]. The specific calculation formula is as follows [86]:

$$G = G_g + \sum I_i P_i G_i + R \tag{2}$$

In Equation (2), G represents the overall GC; G_g represents the GC between different types of cities; I_i, P_i and G_i stand for the proportion of UII, people and GC in Type i city, respectively; and R denotes the Crosses . Items on the right side of Equation (2) divided by G will respectively represent the CR of corresponding sectors to overall inequality.

3.2.3. Measuring Bi-Polarization

Compared with inequality, the research on bi-polarization appeared later, as did its measurement methods. Methodologically, some scholars have directly measured bi-polarization using a range of two poles. Some scholars have also compared the average values of the highest group and the lowest group in proportion, for example, comparing the average income of the top 5% income group with that of the lowest 5% income group to study income bi-polarization. Although these measurement methods can quantify bi-polarization to a certain extent, they do not fully consider the relationship between bi-polarization and inequality. In comparison, Foster and Wolfson proposed the concept of the bi-polarization curve and illustrated the relationship between the bi-polarization curve and the Lorenz curve [28]. Moreover, Wolfson constructed the corresponding bi-polarization index. This paper formulates the bi-polarization measurement function with reference to the bi-polarization index [80]:

$$P = \frac{2(G_B - G_W)}{m/\mu} \tag{3}$$

In Equation (3), P denotes the bi-polarization index whose value represents the degree of bi-polarization where the larger the value, the more serious the bi-polarization. Dividing Chinese cities into two groups by the median of per capita UII, then G_B represents the weighted average of the two groups of GC, namely, $G_B = I_1P_1G_1 + I_2P_2G_2$; G_W denotes the GC between two groups; m represents the median of each city's per capita UII; and μ denotes the average of per capita UII.

3.2.4. Measuring Mobility

Based on the related explanation of mobility in this paper, the mobility of UII between Chinese cities was analyzed by using the mobility index constructed by Wang et al. [87].

$$M = 2n^{-2}\sum_{i=1}^{n}|q_{i,t} - q_{i,b}| \quad (4)$$

In Equation (4), M represents the mobility index where the larger the index, the greater the mobility; its theoretical upper limit is 1 and its lower limit is 0. n denotes the number of Chinese cities; and $q_{i,t}$ and $q_{i,b}$ represent the ranks of per capita UII of City i in the current period and base period, respectively.

It is required that the analysis of mobility not only analyzes its absolute value, but also explores its impact on inequality or bi-polarization [27]. Fields believed that long-term mobility was a progressive indicator of long-term equal distribution and gave the corresponding calculation formula [70]:

$$M(G) = 1 - G(\overline{X})/G(X_b) \quad (5)$$

In Equation (5), $M(G)$ represents the adjustment index of mobility to inequality (Mobility G Index), and the larger the absolute value of $M(G)$, the more obvious the effect of adjustment. If $M(G)$ is positive, mobility can help reduce the inequality of UII between cities. If negative, mobility aggravates the inequality of UII between cities instead. $G(\overline{X})$ denotes the GC of the average value of per capita UII in the current period and base period disregarding price factors; $G(X_b)$ represents the GC in the base period.

Similar to Equation (5), the adjustment index of mobility to bi-polarization can be constructed. The specific calculation formula is as follows [27]:

$$M(P) = 1 - P(\overline{X})/P(X_b) \quad (6)$$

In Equation (6), $M(P)$ represents the adjustment index of mobility to bi-polarization (mobility P index); $P(\overline{X})$ denotes the bi-polarization of the average value of per capita UII in the current period and base period disregarding price factors; and $P(X_b)$ represents the bi-polarization in the base period.

4. Results

4.1. The Overall Inequality of UII in China's Urban System

Using Equation (1), the GC of UII in China's urban system from 2006–2014 were obtained, as shown in Table 1. The GC declined from 0.4467 in 2006 to the smallest value 0.4154 in 2009, and gradually rose back to 0.4535 in 2014, showing a "U-shape" change.

Table 1. The GC of UII in China's urban system.

Items		2006	2007	2008	2009	2010	2011	2012	2013	2014
GC	Absolute value	0.4467	0.4624	0.4384	0.4154	0.4549	0.4350	0.4472	0.4504	0.4535
	Relative value	100	104	98	93	102	97	100	101	102

4.2. The Contributions of Various Cities to the Overall Inequality

4.2.1. The Contributions of Different Administrative Level Cities to the Overall Inequality

Chinese cities are divided from the low level to the high level according to administrative levels: county-level cities, prefecture-level cities, sub-provincial cities and centrally-administered municipalities. Using Equation (2), the GC and corresponding CR to the overall GC were calculated, and represented the inequality within or between cities of different administrative levels and their corresponding CR to overall inequality. The results are shown in Table 2.

First, from the CR of each term to the overall GC, the CR between the cities and prefecture-level cities was the most significant, except for crosses. Of the two, the CR between cities was the highest at all times, but showed a downward trend on the whole, dropping from 49.76% in 2006 to 33.12% in 2014, whereas the CR of prefecture-level cities was always stable at around 25%. The CR of centrally-administered municipalities, sub-provincial cities and county-level cities was obviously lower, with their sum being generally lower than 5%.

Second, from the value of the GC, the GC of county-level cities and prefecture-level cities was always over 0.4, and even exceeded 0.5 in some years, which was greater than those of centrally-administered municipalities and sub-provincial cities.

Table 2. The GC and corresponding CR to the overall GC of different administrative level cities.

Year	Centrally-Administered		Sub-Provincial		Prefecture-Level		County-Level		Between Them		Crosses	
	GC	CR	GC	CR	GC	CR	GC	CR	GC	CR	GC	CR
2006	0.1139	0.73%	0.2741	2.54%	0.4828	23.94%	0.4658	1.92%	0.2223	49.76%	0.0943	21.12%
2007	0.1356	0.83%	0.3096	2.89%	0.4990	24.05%	0.5283	2.05%	0.2044	44.20%	0.1202	25.98%
2008	0.0463	0.31%	0.3000	2.90%	0.4662	23.30%	0.4749	1.95%	0.2125	48.47%	0.1012	23.07%
2009	0.0955	0.64%	0.2105	2.19%	0.4619	25.29%	0.4563	1.81%	0.2070	49.83%	0.0841	20.23%
2010	0.2751	1.52%	0.2342	2.16%	0.5023	27.39%	0.4550	1.51%	0.1698	37.33%	0.1369	30.09%
2011	0.3157	1.90%	0.3273	3.04%	0.4489	25.42%	0.4372	1.68%	0.1513	34.78%	0.1444	33.19%
2012	0.3593	1.97%	0.3184	2.98%	0.4579	24.77%	0.4754	1.98%	0.1496	33.45%	0.1558	34.84%
2013	0.3549	1.70%	0.3378	3.20%	0.4587	25.81%	0.4870	1.94%	0.1385	30.75%	0.1649	36.61%
2014	0.3111	1.70%	0.3372	3.07%	0.4728	25.98%	0.4854	1.79%	0.1502	33.12%	0.1557	34.34%

4.2.2. The Contributions of Different Regional Cities to the Overall Inequality

Chinese cities can be classified into eight regional cities according to the standards proposed by the Development Research Center of the State Council. This regional classification is more accurate than other regional classifications, such as inland and coastal classifications, or eastern, central, and western regional classifications. Specifically, the GC and the CR to overall inequality between the eight regions are greater than that of the other two classifications, which means that inequality between the eight regions provides a higher explanation for overall inequality than that of the other two regional classifications [27]. By the same token as various cities of administrative levels, the GC and corresponding CR in the eight regional cities to the overall GC was calculated by Equation (2). The results are shown in Figures 3 and 4.

From the CR of each term to the overall GC (as shown in Figure 3), except for the crosses, the inequality between the eight regional cities was the main source of overall inequality in China's urban system, and the inequality within each regional city makes a small contribution to the overall inequality. From the temporal characteristics, the CR between the eight regional cities to the overall inequality shows a "U-shape" change, that is, it first decreases, then increases, with its lowest point lying in 2010. In addition, the CR of the crosses to the overall GC remained high constantly, even reaching 58.71% in 2010, which implied that there were many crosses between the eight regional cities.

For the GC of each regional city (as shown in Figure 4), we can see, first, that the GC between the regional cities showed an obvious "U-shaped" trend as it declined from 0.2065 in 2006 to the lowest point 0.1307 in 2010, a drop of 36.71%, after this, it gradually ascended to 0.1699 in 2014. Second, the GC of each regional city was over 0.4 with the exception of NCC (NCC represents northern coastal cities, which include the cities of Beijing, Tianjin, Hebei, and Shandong) and a very few years, which indicated that the inequality of UII within these regions was relatively larger. Finally, the GC of the crosses showed a notable inverted "U-shaped" change in general, as it ascended from 0.1887 in 2006 to the largest value 0.2671 in 2010, and then it gradually decreased to 0.2289 in 2014. Compared with 2010, the GC of the crosses experienced a significant decrease in 2014. As the crosses stand for the crosses between different regional cities, the decrease in the crosses implies the intensifying stratification between eight regional cities.

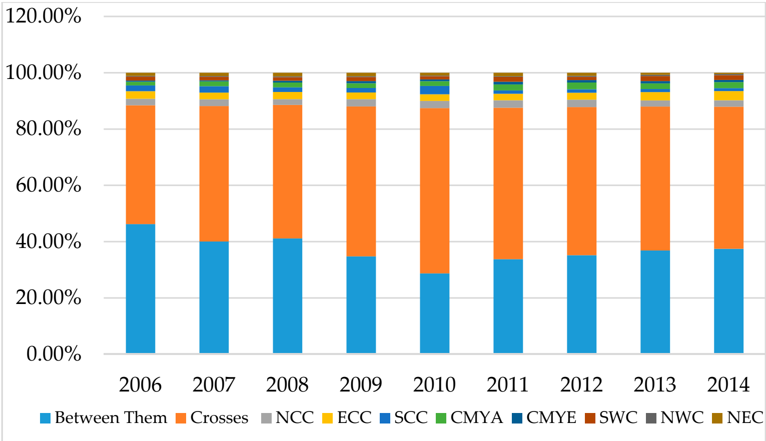

Figure 3. The CR of eight regional cities to the overall GC. Notes: NCC represents northern coastal cities, which include the cities of Beijing, Tianjin, Hebei, and Shandong; ECC represents eastern coastal cities, which include the cities of Shanghai, Jiangsu, and Zhejiang; SCC represents southern coastal cities, which include the cities of Guangdong, Fujian, and Hainan; CMYA represents cities in the middle reaches of the Yangtze River, which include the cities of Hubei, Hunan, Jiangxi, and Anhui; CMYE represents cities in the middle reaches of the Yellow River, which include the cities of Inner Mongolia, Shaanxi, Shanxi, and Henan; SWC represents southwestern cities, which include the cities of Chongqing, Sichuan, Yunnan, Guizhou, and Guangxi; NWC represents northwestern cities, Liaoning, Jilin, and Heilongjiang; and NEC represents northeastern cities, which include the cities of Gansu, Ningxia, Qinghai, Xinjiang, Tibet.

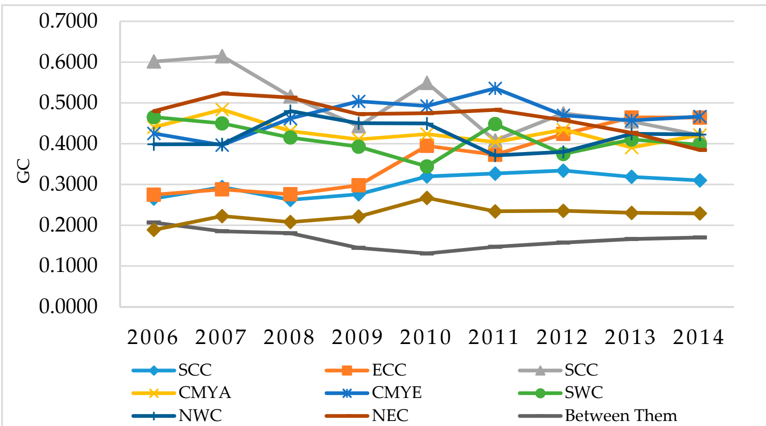

Figure 4. The GC of UII in eight regional cities.

4.3. The Bi-Polarization of UII in China's Urban System

The bi-polarization of UII in China's urban system was calculated though Equation (3), the results of which are shown in Table 3. As the measurement of bi-polarization is not widely used in comparison with the GC, the absolute values of the bi-polarization index were transformed into relative values in this paper, taking 2006 as the benchmark for further understanding of bi-polarization. According to the analysis of the annual level of bi-polarization, the smallest value of the bi-polarization index appeared in 2009, while bi-polarization was most serious in 2010.

Table 3. The bi-polarization index of UII.

Items		2006	2007	2008	2009	2010	2011	2012	2013	2014
Bi-polarization Index	Absolute value	0.5112	0.5194	0.5429	0.4611	0.5969	0.5031	0.5205	0.5120	0.5008
	Relative value	100	102	106	90	117	98	102	100	98

4.4. The Mobility of UII in China's Urban System

The mobility and corresponding regulation index of UII were calculated through Equations (4)–(6), the results of which are shown in Table 4. First, for the mobility index, the mobility index was 0.4857 from 2006 to 2014. Second, for the impact of mobility on inequality and bi-polarization, the mobility G index was 0.0813 and mobility P index was 0.1523, both the mobility G index and mobility P index were positive, while the mobility P index was significantly greater than the mobility G index.

Table 4. The mobility and corresponding regulation index of UII.

Period	M	$M(G)$	$M(P)$
2006–2014	0.4857	0.0813	0.1523

5. Discussion and Policy Suggestions

5.1. The Evolution and Effects of the Overall UII Inequality

Generally speaking, the warning value of the GC was 0.4, and it was noteworthy that a value greater than 0.4 indicated serious inequality. The above results showed that the inequality of UII in China's urban system was already very notable, and was likely to expand gradually later on. Therefore, to promote the coordinated development of Chinese cities and realize the equalization of basic municipal public services, China should attach great importance to the current situation of relatively serious inequality in UII between cities and take further measures to adjust it.

Indeed, UII inequality has seriously hindered China's urban sustainable development: (1) Many Chinese western underdeveloped cities have been confronting a lack of sufficient UII, which has resulted in lower public infrastructure service levels that cannot satisfy the residents' basic needs. For example, many western urban people cannot drink clean water; there is insufficient domestic garbage treatment and wastewater capacities in some cities [14,24]. (2) Serious inequality of UII between cities results in a large inequality in municipal public services between cities, more people have flocked into big cities with higher public services, causing uncoordinated urban development between cities and forming increasingly serious urban disease in big or small cities. Overpopulation in big cities causes the problem of traffic congestion, environmental pollution, and resources; while some cities lack enough people to develop industries and economies [13,15,20,88]. (3) Due to political pressure, many cities look for other local financing channels such as debt and land revenues, which leads to serious local debt and a large amount of unsold new houses as hidden troubles of local sustainable development [33,34].

Actually, balanced UII allocation has been considered the basis of coordinated and sustainable development between cities or regions, thus many countries attach importance to equal allocation of infrastructure funds. Both developed and developing countries take equity as the principle of UII allocation for balanced and stable urban or regional development [3,5,56,89,90]. For example, the Greek government pays more attention to equity than efficiency, and investment tends to be higher in underdeveloped areas in order to reduce regional inequality [91]. In Spain, the central and local government try to balance equity and efficiency when they allocate infrastructure investment, the central government pays more attention to the equity of investment while local government pays more attention to the efficiency of investment [92]. In Chile and Pakistan, equity is viewed as an important standard for infrastructure investment allocation as well [5,93]. However, UII allocation is influenced by many factors such as complicated political and economic factors, thus the principle of equity usually fails to be implemented on the ground [5]. The Chinese central and local governments also confront various complicated situations, which require that the deep reasons behind the growing inequality are found and that a more profound reform of the UII allocation mechanism be conducted.

5.2. The Impact of Cities' Administrative Levels and Regions on the Overall UII Inequality

Based on the CR of various cities, the CR between cities with different administrative level is the most significant except for crosses, and so is the CR between the different regional cities. Thus, China needs to focus on solving the inequality between cities of different administrative levels, as well as the inequality between different regional cities.

Indeed, a city's administrative level and geographic location are regarded as very important factors of the UII amount in many countries [5,90,93,94]. Especially in China, the administrative level and geographic location are regarded as the major determinants of UII by many studies, and many scholars have analyzed the UII inequality between different administrative levels or different regions [13,24,26,36,37].

However, the empirical results show that the CR between cities of different types is about 50% or less than 50%, and crosses between administrative levels and geographic locations are very obvious. This implies that the inequality between different administrative levels or regional cities only partially accounts for the overall inequality based on China's urban system. Therefore, the study of UII inequality needs to be explored from a more systematic and comprehensive perspective, instead of just the administrative level or regional perspective in China.

5.3. Dynamics of the UII Bi-Polarization

As shown in Figure 5, both 2009 and 2010 appeared as the inflection points of the bi-polarization index, the smallest value of the bi-polarization index appeared in 2009, while bi-polarization was most serious in 2010. In response to the financial crisis in 2008, a RMB 4 trillion infrastructure investment plan was issued by the Chinese government, which led to the lowest value of the bi-polarization index in 2009. Due to the plan being initially dominated by the central government, Chinese cities received financial or credit support from the central government to different degrees, which effectively alleviated the bi-polarization between cities. However, the plan also required financial support from local governments. Most cities could keep up with the support at first, but then the disparity of financial support from local governments emerged soon after, especially in cities with limited financial capacity, resulting in serious bi-polarization in 2010.

In general, the bi-polarization index (relative value) of UII in China in the urban system ranged from 90 to 117, indicating the limited variation range of China's UII bi-polarization in the urban system. Compared with GC, the variation range of the bi-polarization index changes was clearly larger than that of inequality, as well this, the performance of the GC and the bi-polarization index were inconsistent. This proved that inequality and bi-polarization have significant differences in both concept and measurement, and there is no necessary connection between them.

Bi-polarization causes social conflicts and much confrontation between groups more easily than inequality [27,28]. UII bi-polarization would not only cause the bi-polarization of economic development and public services between cities, but also the bi-polarization in many other areas such as the cultural identity and urban environment. All this bi-polarization may result in serious social conflicts between different groups, which could threaten social stability and sustainable development. Therefore, aside from adjusting UII inequality, China should also be concerned about the phenomenon of bi-polarization between cities and solve the problem by supporting cities with limited financial capacity from the national level.

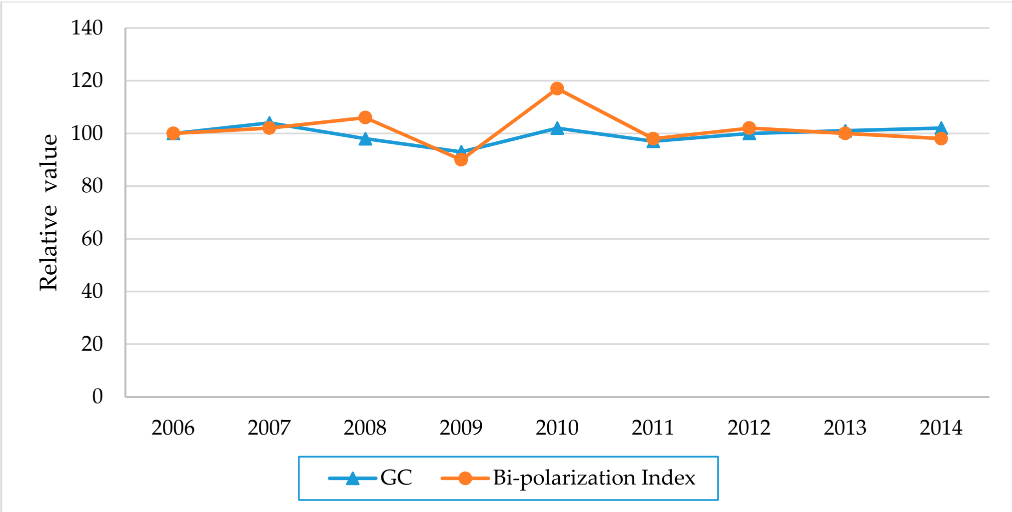

Figure 5. The GC and bi-polarization index of UII in China's urban system (relative value).

5.4. UII Mobility and Its Impact on Inequality and Bi-Polarization

First, for the mobility index, the lower limit was 0, which indicated that the orientation of UII was fixed and rigid, and there was no mobility at all; the upper limit was 1, which suggested the biggest mobility and biggest variation in the orientation of UII between cities in theory. From 2006 to 2014, the mobility index was 0.4857, which meant that the orientation of China's UII was not rigid, and there was a certain mobility between cities. Second, for the impact of mobility on inequality and bi-polarization, both the mobility G index and mobility P index were positive, which showed that long-term mobility played a positive role in narrowing the inequality and bi-polarization of UII between cities.

The Chinese government has always been dedicated to alleviating poverty and reducing regional unbalance. Both the common policy of transfer payments and regional support policies such as the "Western Development Strategy", "Central Grow-Up Strategy" and "Northeastern Re-Rising Strategy" emphasize the importance of supporting infrastructure investment in underdeveloped regions [95]. Thus, some cities in undeveloped regions acquired more UII. Meanwhile, some cities have quite a large degree of development and have more funds for UII, such as Chengdu and Chongqing [81]. Therefore, due to the support policies and cities' own development, UII between cities showed a certain degree of mobility that narrowed the long-term inequality and bi-polarization of UII. Due to the functions of mobility, more efficient policies which contribute to mobility should be introduced and implemented.

5.5. Policy Suggestions

Based on the research of this paper and the reality of China's UII, the following policy suggestions are made:

(1) For the coordinated development of cities and the equalization of basic public services in China, importance should be attached to the unbalance of UII between Chinese cities; necessary measures such as transfer payments, tax returns and project support should also be undertaken to reduce UII inequality and bi-polarization between cities.
(2) Implementing more accurate and targeted UII allocation policies. The empirical results showed that the inequality of UII between various cities can only partially stand for the overall inequality of China's urban system. Namely, if governments implement the UII allocation policies just based on the cities' regional location or administrative levels, it would miss some of the complete information. Hence, it is necessary to adopt more accurate and targeted UII allocation policies based on each city's specific condition.

(3) To break institutional resistance, the private sector should be encouraged to take part in urban infrastructure construction, and promote the effective flow of urban infrastructure construction funds between cities. It is necessary to let the market decide the allocation of resources and better play the role of government in UII.
(4) China's UII should not only ensure the equalization of urban basic public services between cities and realize the coordinated development of cities, but also support and encourage China's national and regional central cities to carry out major infrastructure projects and allow central cities to take the lead in development. Consequently, basic urban infrastructure should be distinguished from non-basic urban infrastructure and a list of basic urban infrastructure should be made.

6. Conclusions

A balanced allocation of UII is significant for sustainable urbanization in periods of rapid urbanization [5]. In this paper, the measurement models of inequality, bi-polarization and mobility of UII were established according to the GC, bi-polarization index and mobility index based on China's urban system. Through empirical study, the main conclusions were drawn as follows: (1) The overall inequality of UII in China's urban system is relatively prominent and shows a "U-shaped" change during the period in general. (2) The inequality between cities of different types only partially contributes to the overall inequality of UII in China's urban system, whether cities are classified in light of administrative levels or regions. (3) The bi-polarization and inequality of UII shows inconsistent performance, and compared to overall inequality, bi-polarization has a greater range of variation. (4) China's UII between cities has a certain mobility, which is significant in order to narrow long-term inequality and bi-polarization.

Compared with the body of existing research, the contributions of this paper lie in: (1) Comprehensively and systematically exploring UII unbalance in China's urban system, which includes inequality, bi-polarization and mobility; (2) Conducting statistical and scientific measurements of UII unbalance; (3) Exploring UII inequality between various cities as classified according to administrative levels or regions, and calculating their contributions to overall inequality; (4) Studying the impact of UII mobility on inequality and bi-polarization.

Although this paper adopted the perspective of China's urban system and studied UII unbalance more comprehensively and systematically, there were still some limitations. First, as the newest edition of the China Urban Construction Statistical Yearbook has not been published yet, the data were only available until 2014. Second, as a method of measuring inequality, the GC is not a panacea and the variables considered can only exist in the formulas. It cannot directly reflect the factors that do not exist in the formulas [23,81,86], such as economic variables, policy variables, environmental variables, etc. Third, we explored the UII unbalance, but lack the analysis of why and how this exists. Consequently, more in-depth and systematic study of the specific problems of UII unbalance needs to be conducted in the future.

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