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A New Approach to Measurement of Regional Inequality in Particular Directions

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Abstract: Regional inequality is a core issue in geography, and it can be measured by several approaches and indexes. However, the global inequality measures can not reflect regional characteristics in terms of spatiality and non-mobility, as well as correctly explore regional inequality in particular directions. Although conventional between-group inequality indexes can measure the inequality in particular directions, they can not reflect the reversals of regional patterns and changes of within-group patterns. Therefore, we set forth a new approach to measure regional inequality in particular directions, which is applicable to geographic field. Based on grouping, we established a new index to measure regional inequality in particular directions named Particular Direction Inequality index (PDI index), which is comprised of between-group inequality of all data and between-group average gap. It can reflect regional spatiality and non-mobility, judge the main direction of regional inequality, and capture the changes and reversals of regional patterns. We used the PDI index to measure the changes of regional inequality from 1952 to 2009 in China. The results show that: 1) the main direction of China′s regional inequality was between coastal areas and inland areas; the increasing extent of inequality between coastal areas and inland areas was higher than the global inequality; 2) the PDI index can measure the between-region average gap, and is more sensitive to evolution of within-region patterns; 3) the inequality between the northern China and the southern China has been decreasing from 1952 to 2009 and was reversed in 1994 and 1995.
Keywords: regional inequality; inequality indexes; PDI index; particular directions; China

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1 Introduction

Regional inequality, as an important manifestation of regional patterns, is one of the core issues in geography. The most common approaches to quantitatively measuring regional inequality are inequality indexes mainly including Coefficient of variation, Gini coefficient, Theil index, Generalized entropy index, Atkinson index, *etc*. (Chen and Belton, 1996; Tsui, 1996; Lu and Wang, 2002; Martin and Christoph, 2008). These indexes are directly applied in the studies of regional inequality. For example, many researchers used these conventional indexes to study the evolution of China's regional inequality in different periods (Tsui, 1993; Jian *et al.*, 1996; Fujita and Hu, 2001; Wan, 2001; Jonathan and Terry, 2002; Max and Wang, 2002; Wei, 2002; Wang *et al.*, 2004; Kanbur and Zhang, 2005; Fan and Sun, 2008; Wei *et al.*, 2009; Rui and Zheng, 2010). However, the initiation of these indexes as pure statistical concepts is more dedicated for inequality of social individual income rather than regional inequality. The regions are characterized by spatiality, directionality and immobility, but these conventional indexes tend to ignore the regional spatial characteristics and thus can not fully reflect the changes of regional patterns. Therefore, to capture the regional inequality in particular direction is indispensable. Therein, the measures of between-group inequality based on the regional subgroups are common approa-

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ches to reflect the directionality of inequality (Kanbur and Zhang, 1999; Huang *et al.*, 2003; Xu *et al.*, 2005). Among various approaches, the decomposition of Gini coefficient and Theil index are two notable methods to explore the directionality of inequality (Akita, 2003; Josef, 2007; Wang, 2007). Besides, Zhang and Kanbur (2001) introduced the concept of subgroup to quantify the polarization in China. These approaches mentioned above are based on the frame of between-group and within-group inequalities, which are derived from the decomposition of indexes. Nevertheless, the problem in empirical study is that the conventional between-group inequality indexes can not capture the reversals of regional patterns and the changes of patterns within the subgroups.

The between-group and within-group inequalities exist simultaneously when researching regional inequality. Taking China as an example, the inequality between coastal areas and inland areas (C-I inequality) became more obvious, meanwhile, the inequalities within these areas also increased sharply (Zhou *et al.*, 2005; Li and Xiu, 2008; Wu and Wang, 2008; Jin and Lu, 2009). Generally speaking, there always exist regional inequality and hierarchy within any country, province or city. Regional inequality is jointly caused by within-group inequality and between-group inequality. But when we study regional inequality in particular directions, between-group inequality tends to be more appealing than within-group inequality. Considering China's regional inequality, we focus more on gap between coastal areas and inland areas (Chen and Belton, 1996; Jian *et al.*, 1996; Yao and Liu, 1996; Lu and Wang, 2002; Kanbur and Zhang, 2005), inequalities among 'three economic belts' (eastern provinces, central provinces, and western provinces) (Fan, 1995; Lee, 2000; Wan *et al.*, 2007), or relationships among 'the four-region divisions' (eastern provinces, central provinces, western provinces, and northeastern provinces) (Xu and Li, 2006; Wang and Xiu, 2010; Qin *et al.*, 2011) rather than their within-region inequalities. Regional policies of the 'Western Development Strategy', the 'Revitalization of Northeast China', and the 'Rise of the Central Region' only aim at narrowing down the gap between less-developed areas and fast growing areas in China. And researchers and government pay less attention to studying the inequalities within these areas. The regional inequality evaluation and policy making are more intimately related to between-group inequality measures. Thus, the frame of between-group inequality should be predominant when we concentrate on regional inequality in particular directions. Special research will be required when we intend to explore within-group inequality.

In this paper, based on the frame of between-group inequality, which is suitable for measuring the variation in particular directions, we explored an alternative approach to measure inequality in particular directions. This new approach is suitable for geographic researchers. Meanwhile, we set forth a new index: Particular Direction Inequality index (PDI index). This index can not only measure between-region inequality and capture the main direction of special inequality, but also reflect the reversals of regional patterns and detect the changes of within-region patterns. After that, taking the mainland of China as a case to study, we took provinces as the analysis units and measured the spatial inequality by the PDI index from 1952 to 2009. Finally, these values calculated by the PDI index were compared with results calculated by the conventional inequality indexes. We aim to provide researchers with the new alternative approach to measure spatial inequality in the field of geography.

2 Limitations of Measuring Regional Inequality Using Conventional Indexes

2.1 Conventional global inequality indexes

2.1.1 Summary of conventional global inequality indexes

The conventional global inequality indexes most commonly used in empirical work include the coefficient of variation (CV), the Gini coefficient (G), the Theil index (T), the Generalized entropy index (GE), and the Atkinson index (A).

(1) The coefficient of variation (CV) is also known as the standard deviation coefficient. Taking the impact of population share in each region into account, the population-weighted coefficient of variation $CV_{(w)}$ (Williamson, 1965) is defined as:

$$CV_{(w)} = \sqrt{\sum_{i=1}^{n}\left(x_i - \mu\right)^2 f(x_i)} \Big/ \mu \tag{1}$$

where x_i is the income for region i; μ is the mean income of all regions; $f(x_i)$ denotes the population share of region i; and n represents the number of regions.

(2) The Gini coefficient (G) introduced by Gini in 1912 is defined as the area between the Lorenz curve and the 45º line (Gini, 1912). The population-weighted Gini coefficient $G_{(w)}$ can be written as (Cowell and Frank, 1995):

$$G_{(w)} = \frac{1}{2\mu} \sum_{j=1}^{n} \sum_{i=1}^{n} f(x_i) f(x_j) \left| x_i - x_j \right| \tag{2}$$

where $| x_i - x_j |$ is the absolute value of the income gap between region i and region j; $f(x_j)$ is the population share of region j.

(3) The Theil index (T) established by Shannon and Wiener (1949) was firstly applied to study the income inequalities across counties by Theil (Theil, 1967), the population-weighted Theil index $T_{(w)}$ can be expressed as follows:

$$T_{(w)} = \sum_{i=1}^{n} f(x_i) \log \frac{f(x_i)}{g(x_i)} \tag{3}$$

where $g(x_i)$ stands for income share of region i as regards to total income of all regions.

(4) The Generalized entropy index (GE) is employed to study the individual inequality based on the concepts of entropy and information content. The less inequality across individuals is, the lower boundary of the Generalized entropy index will be (Shorrocks, 1980; 1984; Liu, 2006). The population-weighted Generalized entropy index $GE_{(w)}$ can be expressed as follows:

$$GE_{(w)} = \begin{cases} \sum_{i=1}^{n} f(x_i) \left[(x_i/\mu)^c - 1 \right] & c \neq 0,1 \\ \sum_{i=1}^{n} f(x_i)(x_i/\mu) \log(x_i/\mu) & c = 1 \\ \sum_{i=1}^{n} f(x_i) \log(\mu/x_i) & c = 0 \end{cases} \tag{4}$$

where c determines the sensitivity of index to the distribution of samples. The Generalized entropy index can be classified as Mean Log Deviation index and Theil index when c approaches 0 and 1 respectively (Liu, 2003).

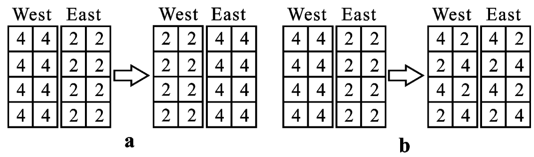
(5) The Atkinson index (A) is an inequality index involving the social welfare concept (Atkinson, 1970), and the population-weighted Atkinson index $A_{(w)}$ is expressed as:

$$A_{(w)} = 1 - \left[\sum_{i=1}^{n} f(x_i)(x_i/\mu)^{1-\varepsilon} \right]^{1/(1-\varepsilon)} \tag{5}$$

where ε is a sensitivity parameter which captures the value of inequality. It is a positive number. The value of ε is in proportion to the weight of low-income individuals.

2.1.2 Limitations of conventional global inequality indexes

On the one hand, the conventional global inequality indexes can not reasonably explicit the spatiality and directionality of regions which reflect spatial changes of regional patterns. For instance, the patterns in the eastern region and western region have been reversed as shown in Fig. 1a; the pattern changed from clustered to dispersed in Fig. 1b. However, the results calculated by conventional inequality indexes indicate no difference between Fig. 1a and Fig. 1b.



4 and 2 represent per capita GDP of every regional unit

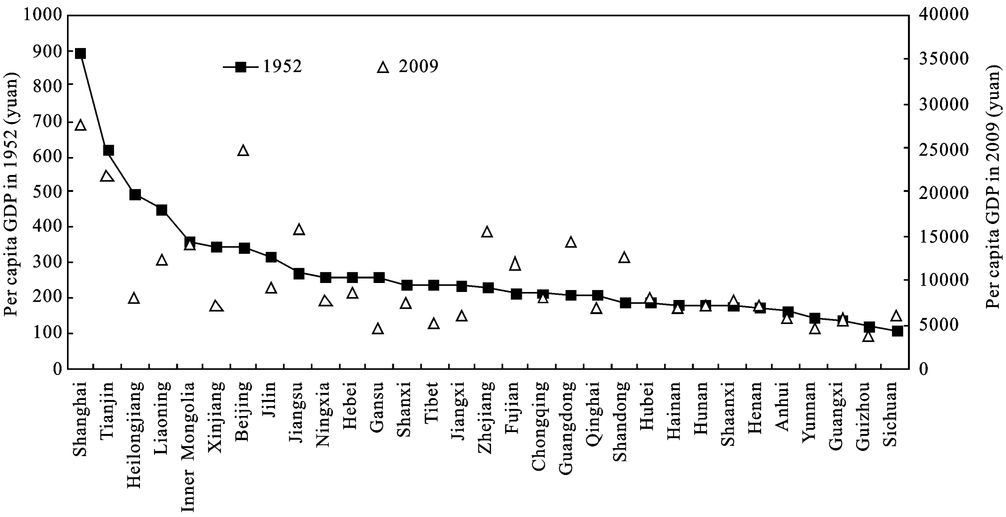
Fig. 1 Two types in evolvement of regional spatial patterns

On the other hand, we can not explore non-mobility of regional samples with the conventional global inequality indexes. In terms of social inequality, it is possible to have identities switched between high-income and low-income people. So the samples can be reordered sequentially according to the income for this kind of inequality. But for the measures of regional inequality, the regional samples themselves have no mobility. Taking the per capita GDP at province level in the mainland of China as an example (Fig. 2), we found that the ranking curve of per capita GDP in 2009 became obviously different from that of 1952. The most typical regions are Beijing and Heilongjiang. Because ranking of samples is an essential process for the use of conventional inequality indexes, the spatial characteristics of regional non-mobility will be disarranged if re-ranking is conducted.

2.2 Conventional between-group inequality indexes

2.2.1 Necessities of measuring regional inequality in particular directions

Considering the limitations of regional global inequality, it is indispensable to measure inequality in particular directions. With regard to regional inequality, we focus



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Sources: Natioal Bureau of Statistics of China (2010a; 2011)

Fig. 2 Evolvement of per capita GDP at province level in mainland of China in 1952 and 2009

on the direction of inequality rather than the degrees how global inequality enlarged or narrowed. For China′s regional inequality, we not only need to explore the changes of global inequality but also need to capture the main direction of inequality, which is more significant for evaluating changes of regional patterns and making regional development policy. The fact that many researchers discuss C-I inequality (Chen and Belton, 1996; Jian *et al.*, 1996; Yao and Liu, 1996; Lu and Wang, 2002; Kanbur and Zhang, 2005), inequality between northern China and southern China (N-S inequality) (Wu, 2001; Li and Qin, 2002), and inequality among ′three economic belts′ (Fan, 1995; Lee, 2000; Wan *et al.*, 2007) demonstrates the necessity of measuring between-group inequality.

Compared with measuring conventional global inequality, measuring the regional inequality in particular directions can capture the two evolvements of regional spatial patterns in Fig. 1. So this process can reflect regional spatiality and directionality to some extent. If regional inequality in particular directions is measured, in theory, the calculated value of the two patterns will be opposite in Fig. 1a, which shows the reversal of regional pattern; and the degree of inequality will be reduced by half in Fig. 1b, which reveals the process from inequality to equality of regional pattern. Furthermore, non-mobility of regional samples can be reflected by measuring inequality in particular directions. Taking China′s C-I inequality as an example, no matter how the order of provincial per capita GDP changes, the samples will be ′confined′ in coastal group or inland group and could not be reordered. Therefore, the measurement of regional inequality in particular directions has prominent academic values and policy interests.

Regional grouping is important to measure regional inequality in particular directions. If the regions are not grouped and only measured by conventional global indexes, the calculated values will not reflect the spatial characteristics of regions. The conventional decompositions of inequality indexes, which mainly include the decomposition of Gini coefficient, the decomposition of Theil index, and the KZ index, *etc.*, are based on the frame of between-group and within-group inequalities raised by regional grouping.

2.2.2 Summary of between-group inequality indexes

(1) Between-group inequality index based on decomposition of Gini coefficient

Bhattacharya and Mahalanobis (1967) proposed a decomposition of the Gini coefficient (G), $G = G_W + G_B$, where G_B is between-group inequality; and G_W is within-group inequality. When we use population-weighted decomposable Gini coefficient and divide the regions into k subgroups, G_B can be written as follows (Cowell and Frank, 1995; Yao, 1999):

$$G_B = 1 - \sum_{i=1}^{n} f(x_k)[2Q_k - g(x_k)] \qquad (6)$$

$$Q_k = \sum_{j=1}^{k} g(x_j)$$

where Q_k is cumulative income share; $f(x_k)$ is population share of subgroup k in total population; $g(x_k)$ means income share of subgroup k in total income; $g(x_j)$ stands for income share of subgroup j in total income.

When we divide the regions into two groups, which are group X and group Y, the inequality between two groups based on the decomposition of Gini coefficient (G_{BT}) can be expressed as follows:

$$G_{BT} = 1 - f(x_1)g(x_1) - f(x_2)[2 - g(x_2)] \quad (7)$$

where $f(x_1)$ is population share of group X in total population; $g(x_1)$ is income share of group X in total income; $f(x_2)$ is population share of group Y in total population; and $g(x_2)$ is income share of group Y in total income.

(2) Between-group inequality index based on decomposition of Theil index

Theil (1967) decomposed the total inequality (T) into within-group inequality (T_W) and between-group inequality (T_B), as $T = T_W + T_B$. Using population-weighted decomposable Theil index, T_B can be defined as:

$$T_B = \sum_{i=1}^{n} f(x_k)\log\frac{f(x_k)}{g(x_k)} \quad (8)$$

The inequality between two groups based on the decomposition of Theil index (T_{BT}) can be written as follows:

$$T_{BT} = f(x_1)\log\frac{f(x_1)}{g(x_1)} + f(x_2)\log\frac{f(x_2)}{g(x_2)} \quad (9)$$

Zhang and Kanbur (2001) proposed the *KZ* index, *KZ* = between-group inequality/within-group inequality. They used decomposable GE index to measure the between-group inequality, which is similar to the decomposition of Theil index.

2.2.3 Limitations of conventional between-group inequality indexes

The conventional between-group inequality indexes, which only reflect the gross interrelation between subgroups, can not capture the changes of within-group patterns. Taking Fig. 3a as an example, the regional pattern of group X has already been changed in time 2, but the values calculated by G_{BT} and T_{BT} reveal no difference in both time 1 and time 2. Besides, the regional patterns have reversed in time 2 as shown in Fig. 3b, but the T_{BT} composed of the sum of subgroups′ inequalities, maintains the same in time 1 and time 2. This suggests that conventional between-group inequality indexes have some limitations with respect to measuring the between-group inequality in regional issues.

3 A New Measurement of Regional Inequality in Particular Directions

3.1 Regional grouping

Regional grouping is a precondition for measuring regional inequality in particular directions. So we applied dichotomy to divide the regions into the high-level group and the low-level group, which is applicable for many situations of regional inequality such as the core versus the fringe, the coast versus the inland, the developed axis versus the outlying area, economic hot spots versus economic cold spots, developed regions versus underdeveloped regions, *etc*. The way how to divide the high-level and low-level groups depends on regional conditions and research needs.

3.2 Measures of between-group inequality of all data

After grouping, the incomes of high-level group can be denoted as: X = $\{x_i\}$, i = 1, 2, 3, …, n, and the incomes of low-level group as: Y=$\{y_j\}$, j = 1, 2, 3, …, m. As per the basic idea of the Gini coefficient, all the data between group X and group Y shall be respectively subtracted and then summated. This process can reflect the interrelationship of all the data in terms of between groups, and be sensitive to the evolution of regional gross patterns caused by changes of within-group patterns. Then, the summation is divided by mn to avoid the case results get disturbed by samples amount. So the absolute amount of between-group inequality of all the

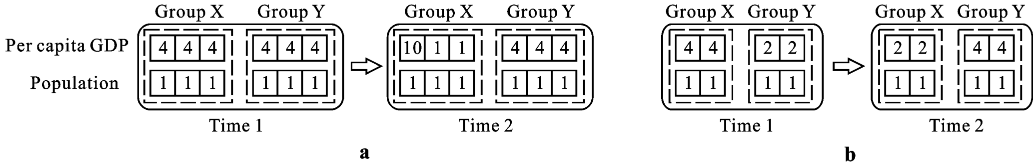


Fig. 3 Two examples of limitations of conventional between-group inequality indexes

data ($I_{H\text{-}L}$) can be written as:

$$I_{H\text{-}L} = \frac{1}{mn}\sum_{j=1}^{m}\sum_{i=1}^{n}\left|x_i - y_j\right| \quad (10)$$

where x_i is the income of region i in group X, and y_j represents the income of region j in group Y; n and m stand for respectively the numbers of regions in group X and group Y.

After that, the $I_{H\text{-}L}$ is divided by the sample mean income (μ) so that it can not be influenced by the order of magnitude of individual income. Hence the inequality of all the data between group X and group Y ($I'_{H\text{-}L}$) can be written as follows:

$$I'_{H\text{-}L} = \frac{1}{mn\mu}\sum_{j=1}^{m}\sum_{i=1}^{n}\left|x_i - y_j\right| \quad (11)$$

Usually, scales of regions are significantly different from each other in regional issues. In China, for example, Guangdong is the largest province, accounting for 7.32% of total population, while Tibet is the smallest, only 0.022%. Hence, it is constructive to consider the population-weighted measurement for issues of regional inequality (Akita and Miyata, 2010; Qin *et al.*, 2011). Taking Fig. 4 as an example, the region C has the highest population size and per capita GDP. Regardless of their population size, it merely calculates relationships among three regions, i.e. A, B, and C, and ignores the relationships among individuals. In this case, the Gini coefficient is 0.5 (Fig. 4a). But if we consider the effect of the various population sizes, the region C where the population size is 4 will be decomposed into four regions, i.e. C_1, C_2, C_3, and C_4. Thus, it is reasonable to calculate the relationships among six regions which are A, B, C_1, C_2, C_3, and C_4. In this case, the Gini coefficient drops down to 0.2857 (Fig. 4b).

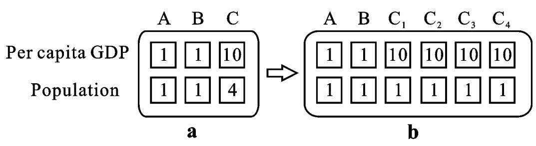


Fig. 4 Contrast of measures between unweighted and weighted inequalities

As pointed out by Akita and Miyata (2010), unweighted inequality measures overstate regional deviations of smaller regions from the national average. When population-weighted measures are applied, the weight of region C will be four times bigger than that of A or B, which is more appropriate. So the use of population-weighted can eliminate the error brought by differing scales of regions.

A common process for population-weighted inequality measures is that population shares of spatial units are used as multipliers. When spatial units multiply by their population shares, the calculated values will obviously decrease, and the sum of calculated values will not change with sample size. So the sum does not have to be divided by mn, which is different from unweighted inequality measures. As mentioned above, the difference between unweighted and weighted inequality formulas of Coefficient of variation, Gini coefficient, Theil index, Generalized entropy index, Atkinson index, *etc.* is whether these indexes are divided by sample size or not (Liu, 2006). In light of this, the population-weighted inequality measures of all the data between group X and group Y ($I'_{H\text{-}L\,(w)}$) can be expressed as follows:

$$I'_{H\text{-}L(w)} = \frac{1}{\mu}\sum_{j=1}^{m}\sum_{i=1}^{n} f(x_i) f(y_j)\left|x_i - y_j\right| \quad (12)$$

where $f(x_i)$ stands for the population share of region i; and $f(y_j)$ is the population share of region j.

3.3 Measures of between-group average gap

The significance of measuring between-group average gap is as follows: 1) it can display the reversals of regional patterns indicated in Fig. 3b by positive or negative values; 2) it can clearly demonstrate the average distance between two subgroups, namely macro gap.

Generally, there are more low-level regions than high-level regions in the regional number of within-subgroups. From this point of view, it is inaccurate to use arithmetic means to measure between-group inequality. For instance, although the arithmetic mean of {1, 1, 1, 1, 26} and {6, 6, 6, 6, 6} are both 6, the regional patterns of these two matrixes are totally different. From the regional development perspective, we can not state that their inequality is 0. Thus, it is necessary that the power mean, which can give more weight to low-level regions, is used for evaluating the development level of subgroups (Atkinson, 1970; Hong, 2008). The power mean of group X (M_X) can be expressed as:

$$M_X = \left(\sum_{i=1}^{n} x_i^{q} \Big/ n\right)^{1/q} \quad (13)$$

where x_i is the income of region i; and q, which is positive number, is a parameter. If $q < 1$, low-level regions will be endowed with more weight, otherwise, high-level regions will be endowed with more weight. We let $q = 0.8$ because the low-level regions have more weight in this paper.

Moreover, the application of the arithmetic mean may lead to errors and will not be able to show the actual income level of within-group because the population scales are different in each region. For example, the income distribution and the population share of group X are {2, 3, 10} and {0.2, 0.2, 0.6} respectively, so the arithmetic mean is 5. But the region where income is 10 has the largest population. If we take the population factor into account, the population-weighted mean will be 7. In addition, the relationship between the population-weighted mean and the arithmetic mean can reflect the situation of population agglomeration in the regions. If the population-weighted mean is higher than the arithmetic mean, the degree of population agglomeration will be higher in high-level regions. The population-weighted power mean of group X ($M_{X(w)}$) can be written as follows:

$$M_{X(w)} = \left(\sum_{i=1}^{n} x_i^q f'(x_i) \right)^{1/q} \tag{14}$$

where $f'(x_i)$ stands for the population share of region i in group X; n is the number of regions in group X. Taking the ranking condition in terms of the distribution of per capita GDP of provinces in the mainland of China in 2009 as an example, the power means and population-weighted power means in high-level and low-level groups are both lower than their respective arithmetic means, which indicates the low-level regions have more population weight and larger proportion (Fig. 5).

The amount of the gap between power means of high-level group and low-level group ($GAP_{H\text{-}L}$) is:

$$GAP_{H\text{-}L} = M_X - M_Y \tag{15}$$

Then, the value above is divided by the sample mean (μ) to keep the invariant of order of magnitude. So the mean gap of between-group ($GAP'_{H\text{-}L}$) can be written as follows:

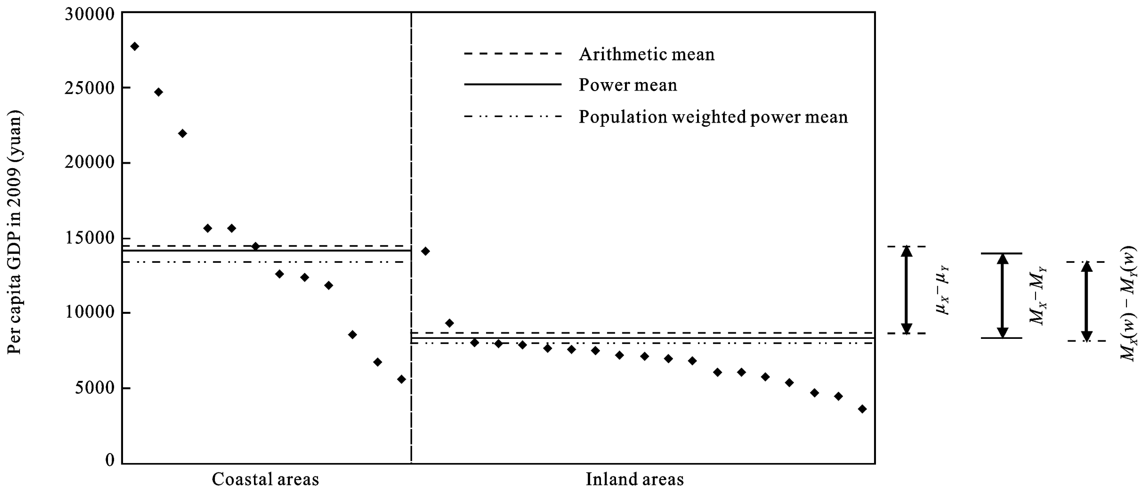
$$GAP'_{H\text{-}L} = \frac{M_X - M_Y}{\mu} \tag{16}$$

The population-weighted mean gap of between-group ($GAP'_{H\text{-}L(w)}$) can be expressed as:

$$GAP'_{H\text{-}L(w)} = \frac{M_{X(w)} - M_{Y(w)}}{\mu} \tag{17}$$

3.4 Establishment of PDI index

The PDI is made up of between-group inequality of all the data ($I'_{H\text{-}L}$) and between-group average gap ($GAP'_{H\text{-}L}$). Hence, the PDI index we proposed can be written as follows:



Price base year: 1990
Source: China Statistical Yearbook (2010b)
$\mu_X - \mu_Y$ represents the gap between arithmetic means of group X (coastal areas) and group Y (inland areas) in per capita GDP;
$M_X - M_Y$ represents the gap between power means of group X and group Y in per capita GDP;
$M_{X(w)} - M_{Y(w)}$ stands for the gap between population-weighted power means of group X and group Y in per capita GDP

Fig. 5 Comparisons between means (arithmetic mean, power mean, population weighted power mean) of per capita GDP of China′s coastal areas and inland areas in 2009

$$PDI = I'_{H\text{-}L} \times GAP'_{H\text{-}L} \tag{18}$$

Thus,

$$PDI = \frac{M_X - M_Y}{mn\mu^2} \sum_{j=1}^{m} \sum_{i=1}^{n} \left| x_i - y_j \right| \tag{19}$$

The population-weighted PDI index ($PDI_{(w)}$) can be expressed as:

$$PDI_{(w)} = \frac{M_{X(w)} - M_{Y(w)}}{\mu^2} \sum_{j=1}^{m} \sum_{i=1}^{n} f(x_i) f(y_j) \left| x_i - y_j \right| \tag{20}$$

3.5 Features of PDI index

(1) The calculated values do not change with the magnitude of samples. And the inequality values of measures will stay the same if the income of each region changes at the same ratio. That is to say, the changes of units or magnitudes of samples can not influence the calculated values that are only related to the proportion of income of each region. For example, if the sample set Z_1: {2, 3, 10} increases 10 times to Z_2: {20, 30, 100}, the inequality values of Z_1 and Z_2 will stay the same.

(2) The calculated values do not change with sample size. That is, the proportional increase or decrease of sample size will not influence the inequality values. For instance, when the sample size of Z_1: {2, 3, 10} is doubled to Z_2:{2, 2, 3, 3, 10, 10}, the inequality values of Z_1 and Z_2 will be consistent.

(3) The calculated values among various grouping methods can be compared. It includes two aspects: on the one hand, when sample sizes between subgroups are the same while the sample incomes are different, their calculated values can be compared. For example, we suppose sample set is Z: {1, 2, 3, 9, 10}. The method of defined subgroups is Z_1: (X = {9, 10}, Y = {1, 2, 3}), when the method is turned into Z_2: (X = {2, 10}, Y = {1, 3, 9}), the within-group inequality of Z_1 will be greater than that of Z_2. On the other hand, when the sample sizes of subgroups are different, their calculated values can be compared. For instance, if methods of defined subgroups are Z_1: (X = {9, 10}, Y = {1, 2, 3}) and Z_2: (X = {2, 9, 10}, Y = {1, 3}), the inequality of Z_1 will be greater than that of Z_2. With this features, we can explore the main direction of spatial inequality.

(4) The calculated values are sensitive to the changes of within-group patterns. For instance, if the regional patterns are Z_1: (X = {4, 4, 4}, Y = {4, 4, 4}) in time 1, and Z_2: (X = {4, 4, 4}, Y = {10, 1, 1}) in time 2, the calculated values will be changed from time 1 to time 2.

(5) The calculated values could be negative, and the changes of signs indicate reversals of regional patterns. If the regional pattern of time 1 is Z_1: (X = {9, 10}, Y = {7, 8}), and that of time 2 is Z_2: (X = {7, 8}, Y = {9, 10}), their signs of calculated values should be opposite. So we can conclude that regional development of group Y surpasses that of group X in time 2.

4 A Case Study: Regional Inequality in China

4.1 Data source and processing

We used Chinese provinces except Hong Kong Special Administration Region, Macao Special Administration Region, and Taiwan Province as the basic analysis units in this paper. Statistical data covered the period from 1952 to 2009 for 31 provinces consist of GDP, population and per capita GDP, which were obtained from China Compendium of Statistics 1949–2008 (National Bureau of Statistics of China, 2010a), China Statistical Yearbook 2009 (National Bureau of Statistics of China, 2010b), and China Statistical Yearbook 2010 (National Bureau of Statistics of China, 2011). The data of per capita GDP of Hainan Province from 1952 to 1977 were assessed by that of Guangdong Province after constrain calculations. Values of per capita GDP were converted into 1990 constant prices, adjusted for inflation so they can be compared directly.

4.2 Empirical results using conventional inequality indexes

4.2.1 Results calculated by conventional global inequality indexes

We used the coefficient of variation, the Gini coefficient, the Theil index, the Generalized entropy index, and the Atkinson index, all of which are population-weighted, to measure the changes of inequality in China over the period 1952–2009. Subsequently, these calculated values of 1952 were converted into 1 so that they can be compared (Fig. 6).

The results calculated by conventional global inequality indexes reflected the fluctuation of inequality in general terms. Two peaks could be found in 1960 and 1976, while three valleys appeared in 1957, 1967 and 1990 respectively. But the results only illustrated China′s overall spatial inequality. In order to judge the main direction of inequality, we need use between-group inequality indexes to measure it.

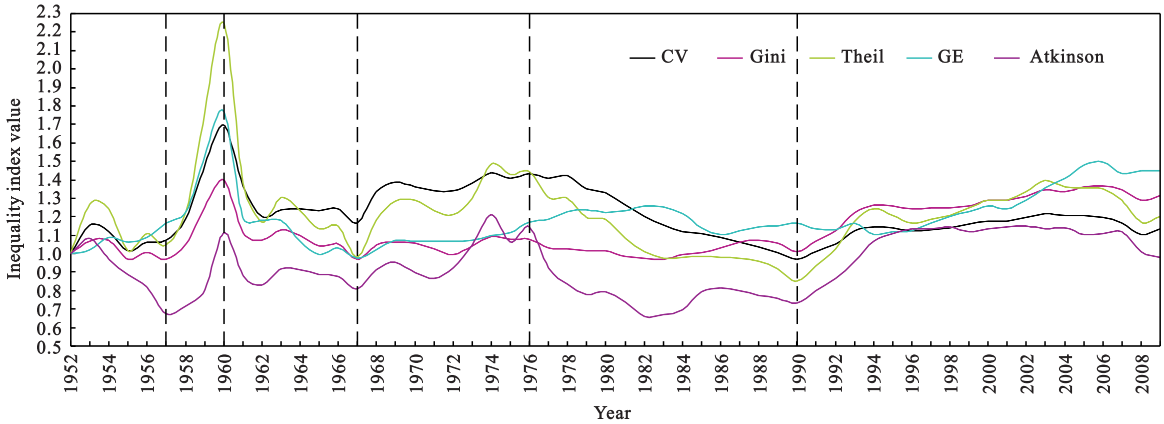


Fig. 6 Regional inequalities measured by conventional global inequality indexes in China from 1952 to 2009

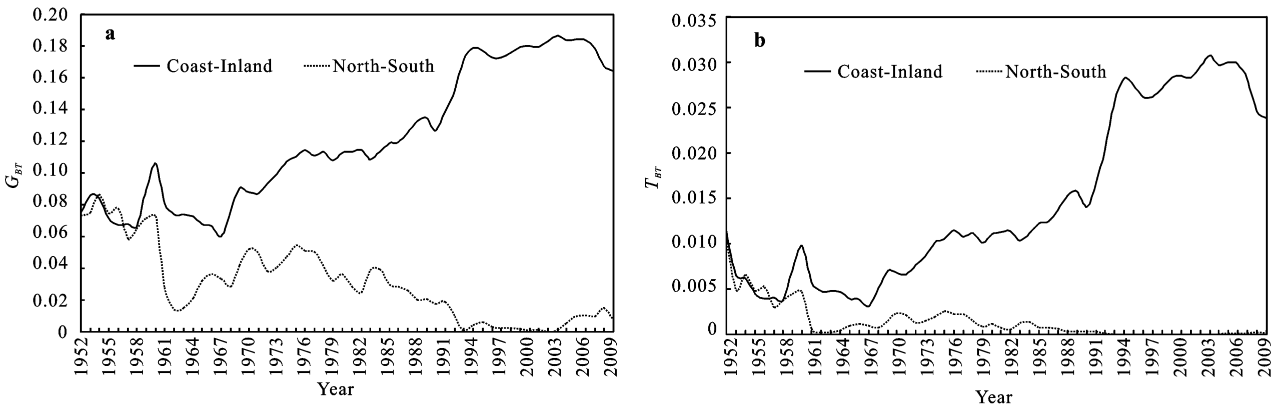
4.2.2 Results measured by conventional between-group inequality indexes

According to previous studies (Zhao, 1998; Long, 1999; Fujita and Hu, 2001; Zhang and Kanbur, 2001; Wu, 2001; Li and Qin, 2002), we used two grouping methods to divide Chinese regions into the high-level group and the low-level group, which are coastal areas versus inland areas and the northern China versus the southern China. Coastal areas include Beijing, Tianjin, Hebei, Liaoning, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi, and Hainan; the others belong to inland areas. The northern China is comprised of Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shandong, Henan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang; the others belong to the southern China.

Using G_{BT} and T_{BT}, we measured the changes of C-I inequality and N-S inequality in China. The comprehensive fluctuate trends of G_{BT} and T_{BT} were similar, and revealed that C-I inequality increased and N-S inequality decreased from 1952 to 2009 (Fig. 7). This suggests the main direction of China's regional inequality is C-I inequality. But these indexes can not capture the reversals of regional patterns and the changes of within-region patterns as shown in Fig. 3.

4.3 Empirical results of PDI index

According to the calculation process mentioned in Section 3, we measured the inequality between two subgroups by the population-weighted PDI index ($PDI_{(w)}$) (Fig. 8). The results revealed that C-I inequality increased fluctuantly and N-S inequality decreased. In 1952, the degrees between C-I inequality and N-S inequality were similar. And then C-I inequality became obvious and N-S inequality disappeared in 2009, which suggests the main direction of China's regional inequal-



G_{BT} is the inequality between two groups on the decomposition of Gini coefficient in per capita GDP;
T_{BT} is the inequality between two groups on the decomposition of Theil index in per capita GDP

Fig. 7 Inequality between coastal areas and inland areas and inequality between northern China and southern China in 1952–2009

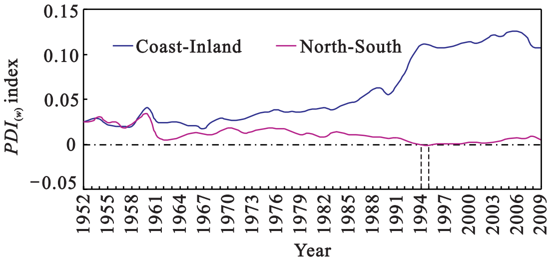


Fig. 8 Fluctuation of $PDI_{(w)}$ in two kinds of subgroups' methods in China in 1952–2009

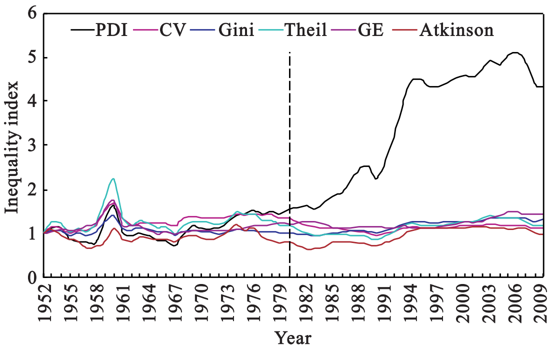
ity is C-I inequality.

In terms of variation trend, C-I inequality increased with fluctuation. From 1990 to 1994, the values increased sharply, and decreased since 2006. And N-S inequality decreased in fluctuation since 1952. Concerning China's N-S inequality, the economic level of the northern China was higher than that of the southern China in 1952, and then the gap became narrow. In 1994 and 1995, the PDI index of N-S inequality became negative values, which indicates that the pattern of N-S inequality reversed and the economic level of the northern China became lower than that of the southern China at that time.

4.4 Comparison between PDI index and conventional inequality indexes

4.4.1 Comparison between PDI index and conventional global inequality indexes

We compared results between the C-I PDI index and conventional global inequality indexes by converting their calculated values of 1952 into 1 (Fig. 9). The results indicated that their distinct calculated values reflected their different theoretical framework. The C-I PDI index was obviously higher than conventional global inequality indexes after 1980, which reveals the ineffectiveness of conventional global inequality indexes as an adequate reflection of C-I inequality's continuous enlargement during this period. On the contrary, the PDI index is capable to capture this and make judgment on the main direction of regional inequality. Furthermore, their similar rise and fall confirmed that C-I inequality played a significant role in global inequality and was the main direction of China's regional inequality.

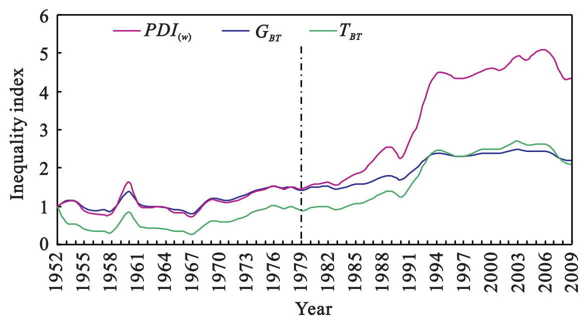


The value of 1952 = 1

Fig. 9 Comparison between $PDI_{(w)}$ and conventional global inequality indexes in China in 1952–2009

4.4.2 Comparison between PDI index and conventional between-group inequality indexes

Fig. 7 and Fig. 8 revealed that the comprehensive fluctuant trends measured by $PDI_{(w)}$, G_{BT} and T_{BT} were similar. But their amounts of variation were obviously different. Taking C-I inequality for example, we converted these calculated values of 1952 into 1 so that the values measured by these three indexes can be compared (Fig. 10). The value of $PDI_{(w)}$ in 2009 was 4.33, which was obviously higher than 2.18 and 2.09 measured by G_{BT} and T_{BT} respectively. The values of $PDI_{(w)}$ and G_{BT} were similar from 1952 to 1979, and then $PDI_{(w)}$ increased sharply and became higher than G_{BT} from 1979 to 2009. That is because the fact that within-regional patterns, measured by Theil index, changed sharply since 1979 (Fig. 11). The coastal within-region inequality decreased sharply, which indicates economic performances of some coastal provinces obviously improved. This evolvement can be captured by the calculation process of $|x_i - y_j|$ in PDI index. The variation of each province will change calculated value of PDI index, but it can not captured by G_{BT} and T_{BT}. The other reason



The value of 1952 = 1

G_{BT} is C-I inequality on the decomposition of Gini coefficient in per capita GDP; T_{BT} is C-I inequality on the decomposition of Theil index in per capita GDP; $PDI_{(w)}$ is the population-weighted PDI index of C-I inequality in per capita GDP

Fig. 10 Comparison of G_{BT}, T_{BT} and $PDI_{(w)}$ of inequality between coastal areas and inland areas in 1952–2009 is the population-weighted between-group average gap ($GAP'_{H\text{-}L(w)}$), which enlarged sharply since 1979, can be captured by $PDI_{(w)}$ (Fig. 12). Therefore, the $PDI_{(w)}$, which can reflect the changes of within-group patterns and between-group average gap, is more feasible for the measurement of regional inequality in particular directions compared with G_{BT} and T_{BT}.

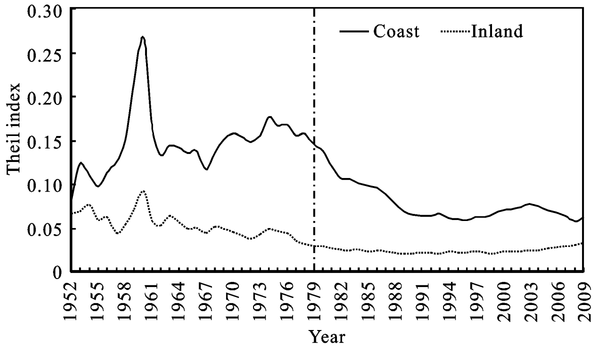
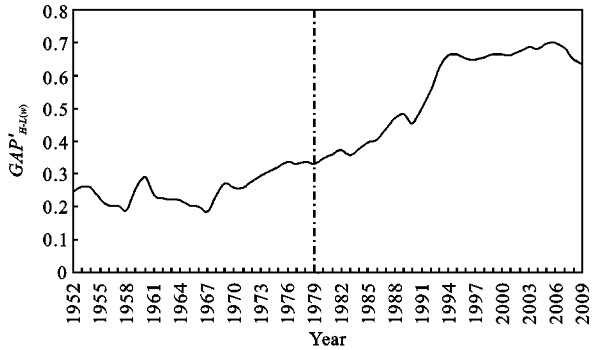


Fig. 11 Theil indexes of coastal areas and inland areas in China from 1952 to 2009



C-I $GAP'_{H\text{-}L(w)}$ is the population-weighted mean gap between the high-level group (coastal areas) and the low-level group (inland areas) in per capita GDP

Fig. 12 C-I $GAP'_{H\text{-}L(w)}$ in China from 1952 to 2009

5 Conclusions

(1) A new measurement applicable for regional inequality in particular directions in geography was proposed. Meanwhile, based on the grouping method, we established the Particular Direction Inequality index (PDI index), which can measure between-region inequality, capture the main direction of special inequality, and reflect the reversals of regional patterns. The PDI index is composed of between-group inequality of all the data and between-group average gap.

(2) The PDI index we proposed has mainly five features: 1) the calculated values do not change with the magnitude and size of sample; 2) the empirical results among various grouping methods can be compared, so that the direction of regional inequality can be judged; 3) the time-series comparisons can also be carried out by using the same grouping method; 4) the calculated values are sensitive to the changes of within-group patterns; and 5) the signs of the calculated values may indicate whether the regional patterns are reversed.

(3) The practical values of this new approach are as follows: firstly, the fluctuation of regional inequality in particular directions can be captured. According to the PDI index, for example, China′s C-I inequality increased with fluctuation and N-I inequality decreased over the period 1952 to 2009. Secondly, the primary direction and degrees of spatial inequality can be judged for various subgroups according to different research needs. For instance, the values of PDI index indicate that the main direction of China′s regional inequality is C-I inequality. Thirdly, the variations of regional patterns can be reflected. The signs of PDI index revealed that the economic level of the northern China became lower than that of the southern China and N-S inequality was reversed in 1994 and 1995.

(4) This new approach will be spatially suitable for measuring high-level and low-level groups such as the core versus the fringe, the developed axis versus the outlying area, developed regions versus underdeveloped regions, *etc*. It will be also applied to judging the degrees and changes of inequality for various subgroups in the same region, which can capture the main direction of inequality and give references to policy-makers.

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