Spatial difference of regional carbon emissions in China

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ABSTRACT

Pressure of China's carbon emission reduction is huge, how to make effective carbon emission reduction policy based on carbon emissions' spatial traits is one of most urgent problem Chinese government is faced with. This paper used Theil index to analyze spatial difference of carbon emissions among the east, central and west regions, and got that inter-regional difference is larger than infra-regional difference, and is the main cause of carbon emissions' regional difference, both inter-regional and infra-regional difference got stable since 2006. Carbon emissions' difference of the west region is biggest, the east region's is smaller, the central region's is smallest. Above results have practical meaning for making carbon emission reduction policy, making effective carbon emission reduction policy must consider carbon emissions' spatial trait, strengthening "common but differentiated" duties, highlighting "fairness and efficiency".

Key words: carbon emissions; difference; Theil Index
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INTRODUCTION

Carbon emissions has become an important issue in the worldwide. In 2007, China became the largest carbon emission country in the world. At Copenhagen meeting in 2009, Chinese government promised by the year of 2020, China would cut down carbon emissions by 40%-50% on the basis of that of 2005. Meanwhile China's urbanization and industrialization is developing rapidly, energy consumption and carbon emissions increase quickly, which lead to carrying capacity of environment becoming smaller and smaller, as a result, cost of emission reduction continues to grow. At the same time, China's regional economic development is unbalanced, resource endowment is different, carbon emissions exist spatial difference. Therefore, considering the fact of China's rapidly developing urbanization, industrialization and unbalanced regional economic development, clarify carbon emissions' spatial difference have important implications for making policies to achieve China's carbon emission target, to distribute reasonable and effective emission reduction duties. This paper analyzed spatial difference of carbon emissions among the east, central and west regions in China, revealed spatial patterns that exists, the results are of vital importance to make effective emission-reduction policies.

2 Data
This paper chose China's 30 provinces which didn't contain Taiwan, Hong Kong and Tibet from 1995 to 2010 as study object, divided these 30 provinces into the east, central and west regions by following the traditional three regions division method, collected carbon emissions, per capital carbon emissions and carbon emission intensity of the east, central and west regions.

According to the estimation methods provided by "The 2006 IPCC Guidelines for National Greenhouse Gas Inventories", carbon emissions can be estimated by consumption of the fuel multiply by carbon emission coefficient of that fuel. Energy consumption (standard coal as unit) of each province can be obtained from "China Energy Statistical Yearbook". According to carbon emission coefficients provided by IPCC, carbon emission coefficient of standard coal is $0.7561t(C)/t$. Therefore carbon emissions of each province can be obtained, furthermore carbon

emissions of the three regions can be obtained. Carbon emission intensity equals carbon emissions divided by GDP, data of carbon emission intensity can be got, too.

To better reflect difference of carbon emissions among the three regions, population of the three regions were considered. Data of population of provinces can be got form "China Statistic Yearbook", thus data of per capital carbon emissions can be got. Data of total carbon emissions, per capital carbon emissions and carbon emission intensity of the three regions were listed in Table 1.

Table 1   Data of total carbon emissions, per capital carbon emissions and carbon emission intensity of the three regions

Year	Carbon emissions/ per capital carbon emissions $(10^4 t)$			Carbon emission intensity $(10^4 t/10^9 ¥)$		
	East	Central	West	East	Central	West
1995	49366 0.96	34199 0.80	16255 0.67	2.40	3.41	3.57
1996	50855 0.98	33656 0.78	17954 0.73	2.21	3.32	3.59
1997	51351 0.96	34245 0.78	18488 0.74	2.01	3.04	3.37
1998	52111 0.97	33413 0.76	18891 0.75	1.85	2.72	3.17
1999	53912 1.00	33517 0.76	18346 0.72	1.74	2.53	2.88
2000	52409 0.92	34670 0.79	19215 0.76	1.54	2.40	2.77
2001	59742 1.07	36526 0.82	20167 0.78	1.60	2.32	2.67
2002	64200 1.14	39721 0.88	22138 0.85	1.51	2.23	2.62
2003	73289 1.29	44579 0.99	25808 0.98	1.52	2.25	2.75
2004	90767 1.59	54114 1.19	29649 1.12	1.65	2.42	2.82
2005	90235 1.55	61239 1.39	32614 1.26	1.45	2.42	2.77
2006	116110 1.98	67711 1.53	35864 1.38	1.63	2.35	2.70
2007	127395 2.15	74641 1.69	39152 1.50	1.56	2.26	2.59
2008	134414 2.24	79288 1.78	41648 1.59	1.47	2.12	2.46
2009	142113 2.35	83617 1.88	44391 1.69	1.40	1.99	2.33
2010	154818 2.48	91248 2.04	48457 1.88	1.35	1.91	2.23

As we can see from Table 1, total carbon emissions and per capital carbon emissions of the three regions increased year by year, carbon emissions and per capital carbon emissions of the east, central and west regions declined by sequence. From data of carbon emission intensity, we can see carbon emission intensity of the east, central and west regions increased by sequence. Above phenomenon is consistent with China's decades of economic growth and its unbalanced regional economic development. In addition, all of the three regions' carbon emission intensity show a declining trend except for a few years rebound, which means China's emission reduction has achieved some progress. From Table 1, it's clearly that there exists carbon emissions difference among the three regions, therefore, in order to make effective emission reduction policy, it is essential to clarify spatial difference of carbon emissions among the three regions.

3 Difference analysis of carbon emissions
Theil index was chosen to analyze the difference of the three regions' carbon emissions. Theil index is an effective index to measure difference, it can divide the total difference into inter-regional difference and infra-regional difference. Considering population factor, this paper measured Theil index of per capital carbon emissions rather than the total carbon emissions of the three regions, by measuring Theil index of inter-region, infra-region, contribution rate of inter-regionalTheil index and infra-regionalTheil index and total Theil index of the east, central and west regions to reveal the spatial difference of carbon emissions among the three regions. Based on the existing literature, we decomposed the Theil index into the following formula.

$$T = \sum_{i} \frac{C_i}{C} * \ln \frac{AC_i}{AC} / \frac{IN_i}{IN}$$

$$Tj = \sum_{i} \frac{C_{ji}}{C_j} * \ln \frac{AC_{ji}}{AC_j} / \frac{IN_{ji}}{IN_j}$$

$$TW = \sum_{i,j} \frac{C_{ji}}{C} * \ln \frac{AC_{ji}}{AC} / \frac{IN_{ji}}{IN}$$

$$TB = \sum_{j} \frac{C_j}{C} * \ln \frac{AC_j}{AC} / \frac{IN_j}{IN}$$

$$T = TW + TB$$

$$RTW = \frac{TW}{T}$$

$$RTB = \frac{TB}{T}$$

T for total Theil index among the three regions, Tj for total Theil index of the east, central and west regions respectively, TW for infra-regional Theil index, TB for inter-regional Theil index. RTW for infra-regional Theil index contribution rate, RTB for inter-regional Theil index contribution rate. i for the 30 provinces that were chosen, j for the three regions that were divided, C, AC, IN for total carbon emissions, per capital carbon emissions and per capital GDP of the three regions, Ci, ACi,INi for carbon emissions, per capital carbon emissions and capital GDP per of province i, Cji , ACji,INji for carbon emissions, per capital carbon emissions and per capital GDP of province i in region j. In the formula, proportion of carbon emissions of province i in region j to total carbon emissions of region j was used as weight to adjust Theil index of the east, central and west region respectively , proportion of carbon emissions of province i in region j to total carbon emissions of the three regions was used as weight to adjust infra-regional Theil index among the three regions, proportion of carbon emissions of region j to total carbon emissions of the three regions was used as weight to adjust inter-regional index among the three regions, Decomposing Theil index into above formula has fully considered population factor, weight, which can reflect regional difference more reliably and truthfully.

According to the above formula, values of Theil index were got. Data of Theil index were showed in figure1,2,3.
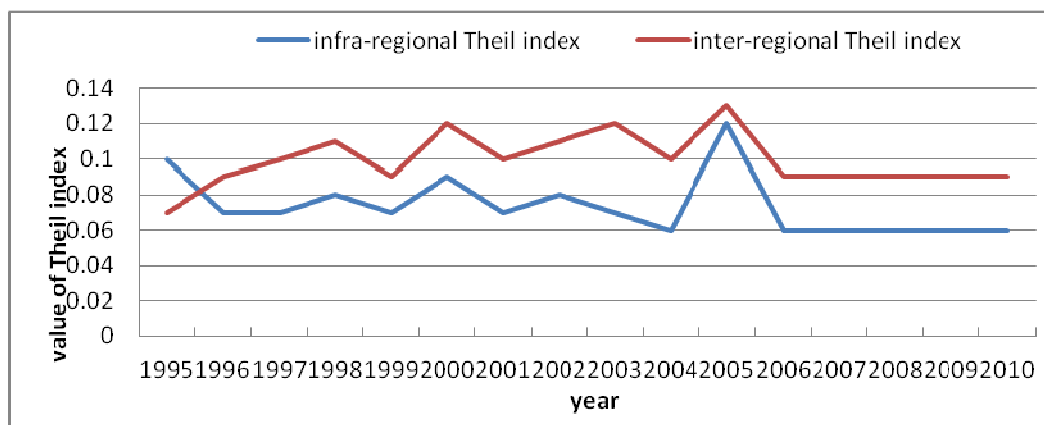

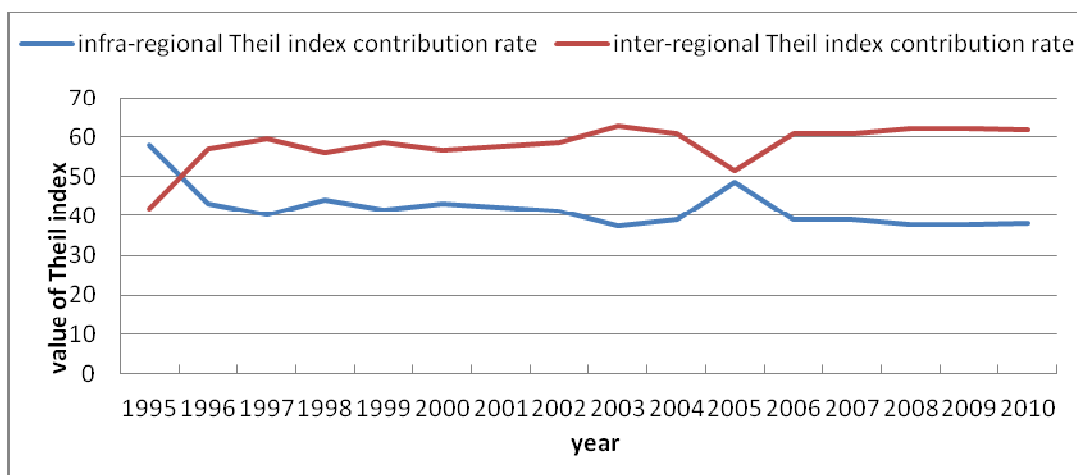**Figure 1. Theil index of per capital carbon emissions among the three regions**

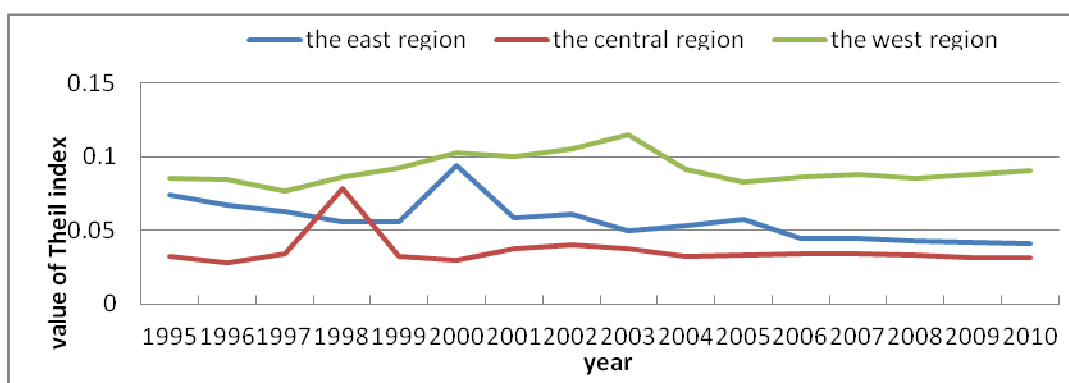**Figure 2. Theil index contribution rate of per capital carbon emissions among the three regions**

Figure 3. Theil index of per capital carbon emissions of the east, central and west regions

From figure 1 we can see that from year 1995 to 2005, both inter-regional, infra-regional Theil index of per capital carbon emissions among the three regions increased, the two Theil indexes achieved peak in 2005, and tended to be stable from year 2006, which means before year 2005, both inter-regional difference and infra-regional difference of per capital carbon emissions among the three regions increased, and got stable from year 2006. It can also be known that, except year 1995, inter-regional difference of per capital carbon emissions is larger than that of infra-regional difference, inter-regional difference is main cause of regional carbon emissions difference. By analyzing figure2, we can know that before year 2003,infra-regional Theil index contribution rate declined, and inter-regional Theil index contribution rate increased, combined with figure 1, it can be got that, though difference of inter-region and infra-region were increasing, increasement of inter-regional difference is larger than that of infra-regional difference. From year 2003 to 2006, infra-regional Theil index contribution rate firstly decreased and then increased, infra-regionalTheil index acts oppositely, and inter-regional Theil index contribution rate got stable at 62% , infra-regional Theil index contribution rate got stable at 38% since year 2006.

From figure 3, it can be known that Theil index of the west region is largest, then followed by that of the east region and that of the west region is smallest, which suggests that difference of per capital carbon emissions among provinces of the west region in largest, that of the east region is smaller and that of the west region is smallest. This is closely connected with economic development of provinces in the three regions, which is in accordance with the economic development gap of provinces in the three regions.

4 Conclusions and suggestions
By using theTheil index to analyze spatial difference of carbon emissions among the east, central and west regions, inter-regional Theil index is larger than infra-regional Theil index, inter-regional difference is the main difference. Inter-regional and infra-regional difference got stable since 2006. Analyzing difference of per capital carbon emissions of the east, central and west regions respectively and got that difference of per capital carbon emissions among provinces of the west region in largest, that of the east region is smaller and that of the west region is smallest.

Above analysis provides theoretical foundation for making effective carbon emission reduction policy, there exists

difference of carbon emissions among different regions and among different provinces in one same region, so when making relative policies, the government must fully considered variation of current status of different regions and different provinces in the same region, strengthening "common but differentiate" duties, highlighting "fairness and efficiency", guarantee policy making and responsibilities respectively, rather than simply highlighting emission reduction. Only by making specific emission reduction distribution that suit for different regions' development reality, can emission reduction achieve progress.

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