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Heterogeneity Analysis on Carbon Emissions of Region using Geographically Weighted Regression

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Abstract: In this study, First, the 30 provinces (autonomous regions and municipalities) are selected as the basic space unit. Then, Geographically weighted regression (GWR) methods are employed to discover the factors and its spatial and temporal distribution for carbon emissions. Finally, the data from China Statistical Yearbook and China energy statistical yearbook from 2003, 2006 to 2010 is adopted to evaluate the reasonability of the proposed method. Our research findings are shown as follows: (1) The regions with a large amount of Carbon emissions are concentrated in mid-east region and its surrounding regions in central and eastern China between 2003 and 2010. (2) Impact factors of carbon emission have spatial temporal heterogeneity. For example, influence extent of GDP is diverse in different province and that the regression coefficients of GDP in 2006 is higher than 2003.Populational influence factors also have heterogeneity among provinces. and that population coefficients in 2006 is higher than 2003. (3) For all of the influence factors, GDP is a significant factor to affect carbon emissions. The evident regions affected by GDP are transferred from western to central and eastern regions in 2003 while those evident regions are transferred back to western regions in 2010. This variation has convincingly proven the complicated relations between carbon emissions and economic growth. To achieve carbon emission reduction effectively, it is significant to adjust economic structure development and improve the energy utilization efficiency.

Key words: Geographically weighted regression, carbon emissions, spatial and temporal heterogeneity, driving factors

INTRODUCTION

Over the past century, with the increasing emissions of greenhouse gases such as carbon dioxide, the atmospheric greenhouse effect has been increasing, the serious consequences caused by the natural environment (Chen, 2009; Liu *et al*., 2008; Wang, 2010; Tukenmez and Demireli, 2012). China's economy is in rapid development stage, energy consumption growing which will appear the carbon emissions increase. How to develop reasonable reduction policy implementation international commitments is a major problem facing, how to correctly evaluate the regional carbon emissions, effective mitigation measures is a priority.

Due to different level of development of China's provinces, there are large difference between regional development actual situation, at present many scholars combined with regional differences on the influence factors of carbon emissions from a research on the scale and methods on a wealth of research. Sun (2010) research by LMDI decomposition methods from the national scale, such as the energy consumption intensity of driving factors and examines the various influence factors on carbon emissions characteristics and difference in carbon industry Zhao and Yang (2012). Based on the data of the industry sector from 2000 to 2009 studied various driving factors impact on carbon emissions changes of our country. Other scholars research from provincial scale, such as Zhang (2008), quantitative regression analysis was used to study the influencing factors of regional energy consumption intensity. Li and Wang (2010), using the grey correlation analytic method in jiangsu province from 1996 to 2007 different correlation factor of carbon emissions and, in turn, are analyzed the influence degree of various driving factors of carbon emissions in jiangsu province. Zhang (2011) analysis the main factors affecting China's carbon emissions using Kaya models.

Almost methods are based on the time series to establish global model, tend to cover up the spatial differences and spatial dependency, ignore the spatial effect of various driving factors of carbon emissions. Due to China's vast territory, different regions of the role of

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the driving factors of carbon emissions will be differences, Geographically Weighted Regression (GWR) model is an extension to the traditional Regression model, allows the parameters estimation of local rather than global, to express spatial object itself through additional correlation and heterogeneous parameters change, reflecting the sample contributes to the Regression equation on the space differentiation, the Regression results more credible (Fotheringham *et al*., 1996; Tang *et al*., 2012). Using the GWR model, therefore, the regional differences and driving factors of carbon emissions, can be added into the model, a more objective study to the heterogeneity of spatial data.

METERIALS AND METHODS

There are many scholars empirical analysis on driving factors of carbon emissions, mainly using the LMDI (Ang, 2005; Balezentis *et al*., 2011; Huang *et al*., 2012; Song and Lu, 2009), STIRPAT (Wang *et al*., 2012; Wang *et al*., 2012; Zhang and Lin, 2012.) and Kaya (Jung *et al*., 2012; Yang, 2012) factors such as decomposition model, discusses the influence factors of energy carbon emissions as well as the influence degree, the analysis of the affecting factors of carbon emissions covers the economic scale, population, energy structure, industrial structure and energy efficiency factor. Based on the reference above, on the basis of relevant research results, we choose five indicators such as GDP, per capita GDP, population, the proportion of secondary industry and energy consumption intensity to measure energy consumption carbon emissions.

The data from China Statistical Yearbook and China energy statistical yearbook from 2003, 2006 to 2010 is adopted to evaluate the reasonability of the proposed method. Carbon emissions calculation based on carbon emissions calculation method by the IPCC 2006, GDP using the comparable price.

The IPCC for energy carbon emission calculation is as follows (IPCC, 2006):

$$A = \sum_{i=1}^{N} B_i C_i \tag{1}$$

A is carbon emissions (ten thousand tons), C_i for energy carbon emission coefficient which the IPCC calculation guide default values and calculated (Zhao *et al*., 2009); B_i is the kind of energy I fold of standard coal quantity (ten thousand tons), fold of standard coal amount converting x fold BiaoMei coefficient which converting of the terminal energy consumption of energy, I fold BiaoMei coefficients from the " National Bureau of Statistics of China, 2011" (Energy Bureau National Statistics Industrial Transportation Statistics, 2011); N is the energy category, a total of 17 classes (including the raw coal, XiJingMei, coke, coke oven gas and other gas, other coking products, crude oil, gasoline, kerosene, diesel oil, fuel oil, liquefied petroleum gas, refinery dry gas and other petroleum products, natural gas, heating and power).the parameter of GWR is changes with the local geography space, is convenient to announce the of spatial relations of carbon emissions observed value and the influence factors, the model structure (Fotheringham *et al*., 2002):

$$y_i = \beta_0(\mu_i, \nu_i) + \sum_k \beta_k(\mu_i, \nu_i) x_{ik} + \varepsilon_i \tag{2}$$

where, y_i is observed value of carbon emission in sample (μ_i, ν_i); x_{ik} is observed value of k impact factors of carbon emission in sample point (μ_i, ν_i); $\beta_k(\mu_i, \nu_i)$is a function of geographic location; ε_I is error which obey normal distribution. In this paper weighting function is Gaussian function, using AIC and kernel density estimation for bandwidth (Brunsdon *et al*., 1996; Bowman, 1984; Brunsdon *et al*., 1999).

RESULT AND DISCUSSION

The stepwise regression method are used to eliminate the linear correlation between factors. Three independent variables of modeling are respective by 2003 and 2010 gross value of production (GDP), population (POPU), energy consumption intensity (ENER_USE).but production (GDP) and energy consumption intensity (ENER_USE) by 2006.

GWR model can explain 73.02-85.27% of carbon emission in 2003, 38.46-81.28% in 2006 and 80.16-89.26% in 2010 in according to Table 1. From the spatial variability of local R^2, fitting degree is higher in southwest province than northeast in 2003 but contrary in 2006; Fitting degree is high in northeast, northwest and south but low in middleast.

According coefficient of carbon emission, parameter estimation results of three independent variable are difference which influence of independence variable is spatial variation. Influence of GDP is obvious and become

Table 1: GWR Evaluation results of carbon emission of 30 provinces in China

	Indication value		
Time	2003	2006	2010
Indication			
Local R^2	0.7302-0.8527	0.3846-0.8128	0.8016-0.8926
R^2	0.8281	0.8314	0.9231
Adjust R^2	0.7849	0.7701	0.8811
SSE	0.3367	0.2999	0.1292
AICc	-31.5307	-31.0013	-46.9744

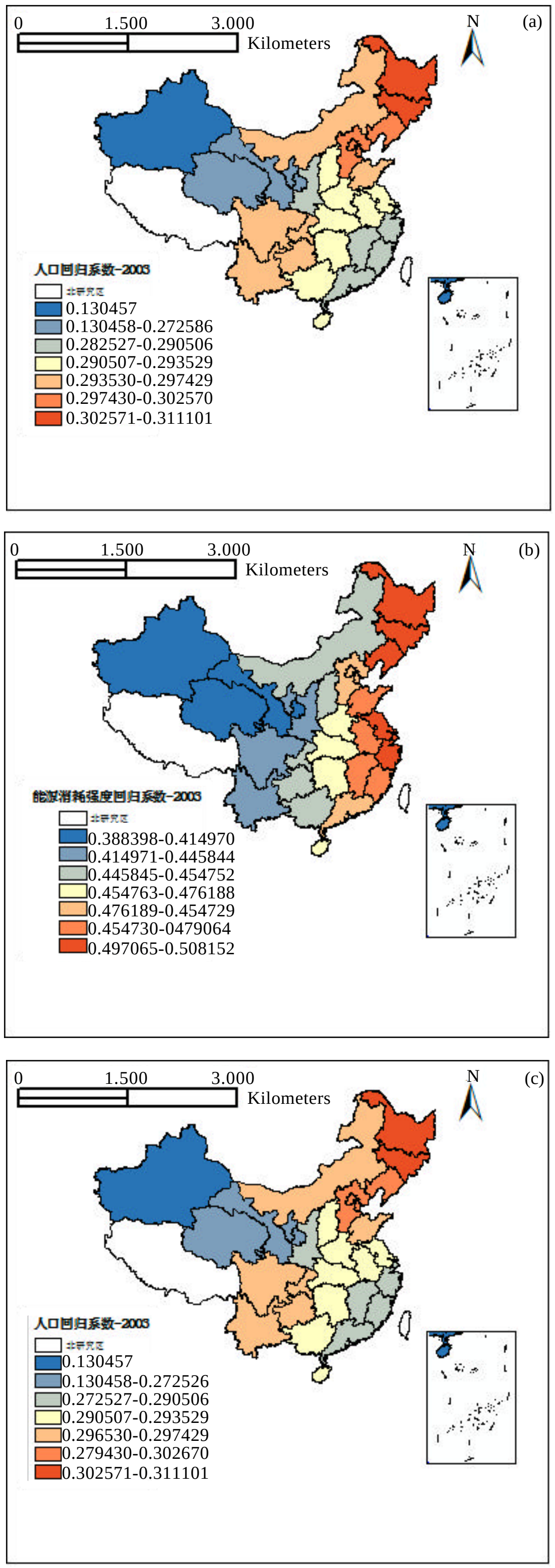

Fig. 1: Local coefficient of carbon emission in 2003

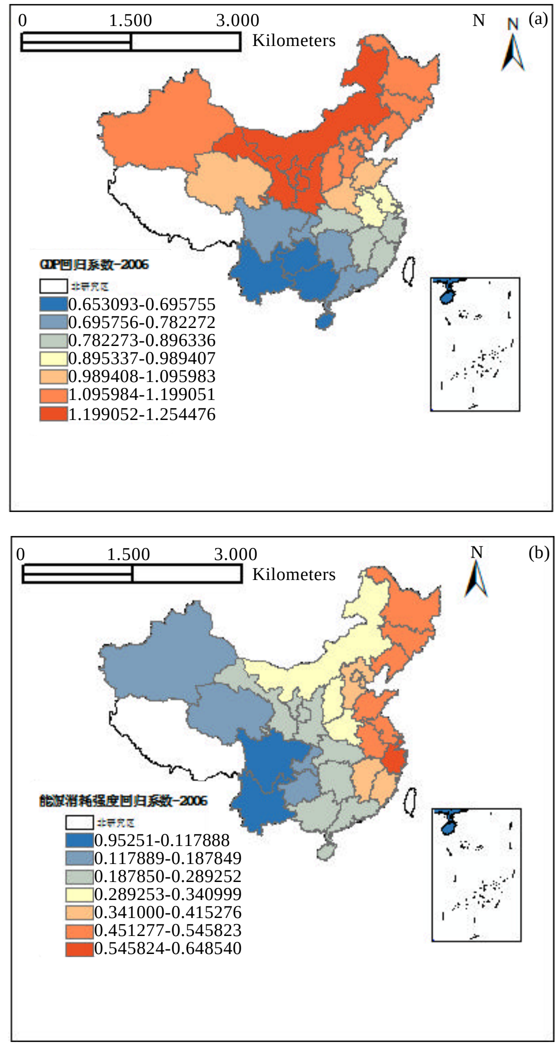

Fig. 2: Local coefficient of carbon emission in 2006

positive correlation with carbon emissions. Influence maximum of GDP is XinJing, minimum focus on GuangDong, GuangXi and HaiNan. GDP changed 1% while carbon emission changed 1.09%. In other word, GDP increasing is more important to carbon emission in the area.

The influence of energy consumption intensity is second. Influence minimum of Energy consumption intensity mainly focus on the west area such as XinJiang, GanSu and QingHai, and more and more influence from here to southeast. Minimum focus on northeast, JiangSu, ShangHai and ZheJiang. Compare to GDP and energy consumption intensity, population influence is weaker.

Carbon emission factors in 2006 are difference from it in 2003, GDP and energy consumption intensity being mainly factors in Fig. 1. Influence of GDP is obvious and

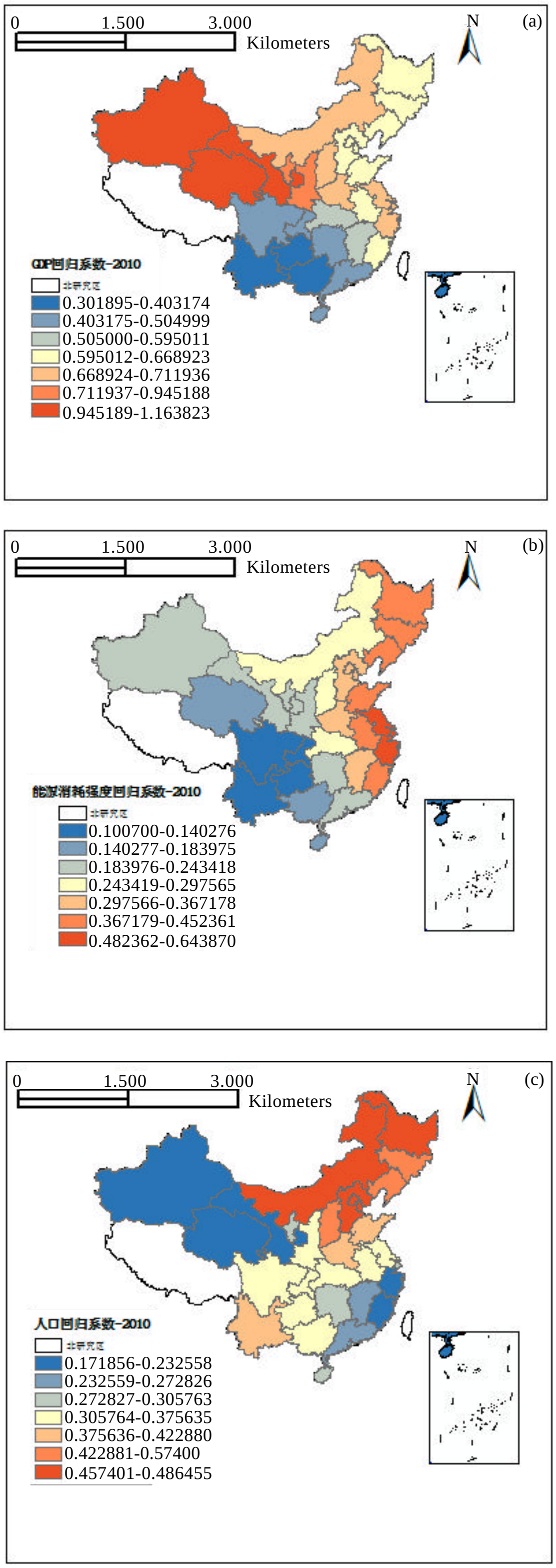

Fig. 3: Local coefficient of carbon emission in 201

center of affect is move from west to northeast. Coefficient of GDP is up 1.2 in GanSu, NingXia, ShanXi, NeimengGu, that showing GDP changed 1% while carbon emission changed more than 1.2%.

Influence factors of carbon emission is still GDP, population and energy consumption intensity in 2010 but influence degree is different from 2003 and 2006. GDP and energy consumption intensity in 2010 is almost in line with 2003. Coefficient of population is higher than 2003, which indicate increase in population impacting on carbon emission.

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