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Analysis of the decomposition of factors affecting energy-related carbon emissions in Guangxi province, China

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. Present study also indicated the industrial structure of Guangxi was characterized with high-energy consuming industries since 2004. The rapid urbanization changed the population structure of Guangxi, being a leading driver of carbon emissions, by examining the regional development inequalities in China and Guangxi, this study suggested the governments should develop special policies for creating a pathway towards sustainable, low-carbon development for under-developed minority-inhabited areas rather than setting non-regional differences emissions targets.

[Key words: Energy consumption; Carbon emission; Factor decomposition; LMDI model; Regional development inequality]

Introduction

According to the IPCC (Intergovernmental Panel on Climate Change) Fifth Assessment Report, it is 95% certain that humans have caused most of the global warming of the last half-century[1]. Therefore, the energy-related greenhouse gas emissions, including carbon dioxide, methane and some traces of nitrous oxide mainly due to energy-related greenhouse gas emissions, have drawn the concern of governments and people worldwide[2-6]. As the world's second largest economy, China also is the world's leading primary energy consumer. China accounted for one-quarter of global carbon dioxide emissions in 2011 and 80% of the world's rise in CO_2 emissions since 2008[7].

Guangxi Zhuang Autonomous Region (GZAR) is an autonomous region of southern China, bordering by Vietnam in the southwest and Beibu Gulf in the south (Fig.1). Guangxi has an area of 2.37×10^5 km^2 in total with a population of 46 million. Specifically, this region has over 14 million Zhuang, the largest minority ethnicity of China. While some development of heavy industry occurred in the 1960s and 1970s, the province remained largely a scenic tourist destination for its natural landscape. As well as many western provinces in China, Guangxi is poor in oil gas resources but rich hydropower resources.

Fig.1 Location of study area

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The eastern part of China benefited greatly from the policy of reform and opening up since 1978, and their economies quickly raced ahead. However, the economy of western China lagged behind severely. As an under-developed region in western China, Guangxi's economic development has lagged behind national average. Guangxi's 2011 nominal GDP was about 1171.4 billion yuan (US$185.9 billion) and ranked 18th in China, and its per capita GDP was 15,800 yuan (US$2,300). Nevertheless, thanks for the regional coordinated development policy and western China's development strategy, Guangxi had faster economic growth compared with Eastern China areas in recent years. Most studies concentrate on drivers of carbon emissions for developed areas rather than under-developed areas in China[8-15]. Although some researchers studied energy consumption in Guangxi[16-22], few of them examined energy-related carbon emissions both from productive and household sectors, and few study highlighted the influence of dual structure for urban and rural carbon emissions in Guangxi. In order to coordinate the relation between economic development and energy consumption in Guangxi, the influential factors of carbon emissions require further exploration.

In this research, carbon emissions of energy consumption from 1995 to 2010 in Guangxi were computed and the influential factors of carbon emissions were analyzed. Furthermore, the contributions to carbon emissions by energy intensity, industry structure adjustment, economic development and population size were examined, and the amounts of carbon emissions from different household sectors were computed individually to study the effects of population structure on carbon emissions for Guangxi. Finally, this study try to analysis regional development inequalities in China, in order to help decision-makers select a sustainable low-carbon road map for Guangxi.

Materials and Methods

In this research, energy is divided into two sectors: termed Productive and household. Productive energy consumption refers to the energy used for three strata of industry. Specifically, primary industry includes agriculture, forestry, animal husbandry, fishery and aquaculture. Secondary industry includes manufacturing and construction industry. Tertiary industry includes transportation, storage, mail business, wholesale, retail industry, accommodation and catering services. It is notable that energy consumption by the industry sector includes the End-use energy consumption by industry sectors and energy consumption of thermal power and heat power production. In contrast, the household energy consumption includes the energy for urban and rural residents and communal facilities, which can be classified into urban energy consumption and rural energy consumption (Fig. 2). According to China Energy Statistical Yearbook, there are 18 types of energy in Guangxi, including raw coal, washed clean coal, other washed coal, briquettes, coke, coke-oven gas, other coal gases, gasoline, kerosene, diesel oil, fuel oil, liquefied petroleum gas, refinery gas, natural gas, other petroleum products, other coking chemicals, hydropower. The equation of total amount of carbon emission is as follows:

$$C = \sum_i \sum_j C_{ij} = \sum_i \sum_j E_{ij} \times f_j \qquad (1)$$

where C represents carbon emissions from energy consumption; i represents the type of industry (i=1, 2, 3) or the type of population (rural population or urban population) (i=4, 5); j represents the type of energy; C_{ij} refers to the carbon emissions of energy j in industry i ; E_{ij} refers to consumption of energy j in industry i; f_j refers to carbon emission coefficient of energy j. As shown in Table 1[23], the unit of carbon emissions was “ton Carbon/ton standard coal equivalent” or “tC/tSCE” of coke oven gas, other gases, and natural gas, and the coefficient of carbon emission was from reference[24]; the coefficients of carbon emission from coke oven gas and other gases were are calculated according to the relationship between their calorific value and natural gas’; the unit of other energies was “ton C/ton” or “tC/t”. Carbon emission coefficient = net calorific value × carbon content, net calorific value and carbon content are from 2006 IPCC Guidelines for National Greenhouse Gas Inventories [25].

Previous studies have established different models of energy-related carbon emissions from energy consumption [26-32]. For its advantage of satisfying the requirement of factor reversible and the residual item eliminated, the LMDI (Logarithmic Mean Divisia Index) method have been widely used in decomposition of factors affecting energy-related carbon emissions[33]. It is obviously that the data of zero or negative is impossible to be processed in LMDI method, however, this problem is successfully resolved by previous research[26].

In this research, the extension models of production and living were established based on Kaya identity[34] and LMDI. Total energy-related carbon emissions (C) is the sum of energy-related carbon emissions from productive sector C_1, and that from household sector C_2, as follows:

$$C = C_1 + C_2 \qquad (2)$$

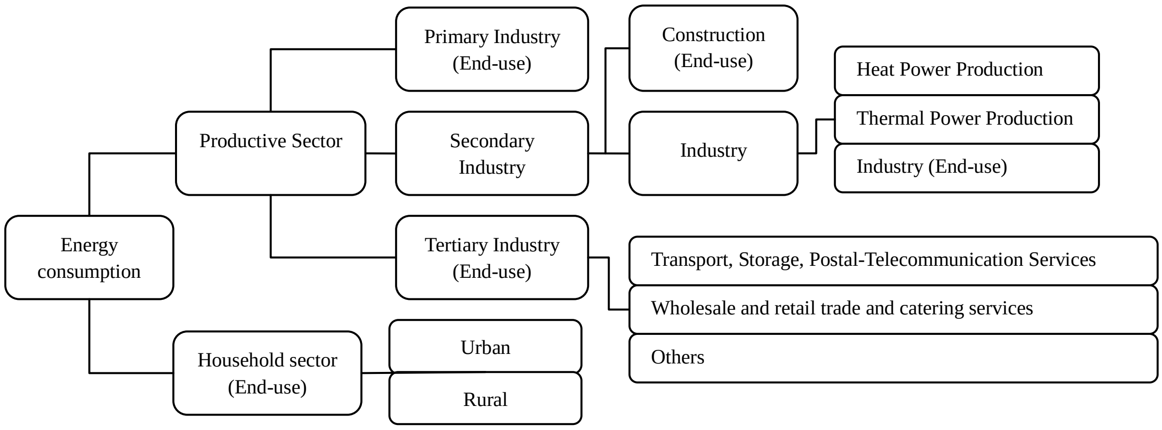

Fig.2 The division of energy consumption

Table 1. Carbon emission coefficients of different kinds of energy

Energy Type	Net Calorific Value /(TJ·10^{-3}t^{-1})	Carbon Content /(t·TJ^{-1})	Carbon Emission Coefficients /(t·t^{-1})	Energy Type	Net Calorific Value /(TJ·10^{-3}t^{-1})	Carbon Content /(t·TJ^{-1})	Carbon Emission Coefficients /(t·t^{-1})
Raw Coal	20.70	26.60	0.551	Kerosene	43.80	19.60	0.858
Washed Clean Coal	28.20	25.80	0.728	Diesel Oil	43.00	20.20	0.869
Other Washed Coal	28.20	25.80	0.728	Fuel Oil	40.40	21.10	0.852
Briquettes	20.70	26.60	0.551	Liquefied Petroleum Gas	47.30	17.20	0.814
Coke	28.20	29.20	0.823	Refinery Gas	49.50	15.70	0.777
Coke-oven Gas			0.197	Natural Gas			0.444
Other Gas			0.197	Other Petroleum Products	40.20	20.00	0.804
Crude Oil	42.30	20.00	0.846	Other Coking Products	28.20		0.823
Gasoline	44.30	18.90	0.837	Hydro Power		0.00	0.000

Model for decomposition of factors affecting energy-related carbon emissions from Productive sector

Previous studies have demonstrated that it is the economic output rather than the population size makes the most contribution to the carbon emissions in the Productive sector[15]. Therefore, the effect of GDP on Productive sectors was highlighted and the decomposition model of carbon emissions from productive sector based on Kaya identity was concluded in this research, as follows:

$$C_1 = \sum_{i=1}^{3}\sum_{j=1}^{18}\left(\frac{C_{1ij}}{E_{1ij}}\cdot\frac{E_{1ij}}{E_{1i}}\cdot\frac{E_{1i}}{GDP_i}\cdot\frac{GDP_i}{GDP}\cdot GDP\right) \qquad (3)$$

where C_{1ij} represents the amount of carbon emissions from the j^{th} energy in the i^{th} industry; E_{1ij} is the consumption of the j^{th} energy in the i^{th} industry; E_{1i} is the energy consumption of the i^{th} industry; GDP$_i$ represents the Gross Domestic Product of the i^{th} industry.

Let $f_{1ij} = \frac{C_{1ij}}{E_{1ij}}$, $m_{1ij} = \frac{E_{1ij}}{E_{1i}}$, $d_{1i} = \frac{E_{1i}}{GPD_i}$

$$s_{1i} = \frac{GDP_i}{GDP}, \quad g = GDP$$

the equation (3) can also be expressed as follows:

$$C_1 = \sum_{i=1}^{3}\sum_{j=1}^{18}(f_{1ij}\cdot m_{1ij}\cdot d_{1i}\cdot s_{1i}\cdot d_{1i}\cdot \mathrm{g}) \qquad (4)$$

where f_{1ij} is the coefficient of carbon emission; m_{1ij} is the proportion of the energy j in energy consumption of industry i; d_{1i} is the energy consumption per unit GDP in the i industry; s_{1i} is the proportion of GDP of the industry I, g is GDP.

Assuming that C_0 refers to carbon emissions in base period and C_T refers to carbon emissions in target year, the changes of carbon emissions (⊿C) can be concluded as follows:

$$\Delta C = C_T - C_0 \qquad (5)$$

In the Productive sector, the expression for the contribution of the decomposed factors to the energy-related carbon emissions are as follows:

$$\Delta C_{1f_{ij}} = \sum_{i=1}^{3}\sum_{j=1}^{18} \alpha \ln \frac{F_{1ij}{}^{T}}{F_{1ij}{}^{0}} \quad (6)$$

$$\Delta C_{1m_{ij}} = \sum_{i=1}^{3}\sum_{i=j}^{18} \alpha \ln \frac{M_{1ij}{}^{T}}{M_{1ij}{}^{0}} \quad (7)$$

$$\Delta C_{1d_{i}} = \sum_{i=1}^{3}\sum_{j=1}^{18} \alpha \ln \frac{D_{1i}{}^{T}}{D_{1i}{}^{0}} \quad (8)$$

$$\Delta C_{1s_{i}} = \sum_{i=1}^{3}\sum_{j=1}^{18} \alpha \ln \frac{S_{1i}{}^{T}}{S_{1i}{}^{0}} \quad (9)$$

$$\Delta C_{1g} = \sum_{i=1}^{3}\sum_{j=1}^{18} \alpha \ln \frac{G^{T}}{G^{0}} \quad (10)$$

where $\alpha = \frac{C_{1ij}{}^{T} - C_{1ij}{}^{0}}{\ln C_{1ij}{}^{T} - \ln C_{1ij}{}^{0}}$, $\varDelta C_{1fij}$、$\varDelta C_{1mij}$、$\varDelta C_{1di}$、$\varDelta C_{1si}$ and Cg represent carbon emission coefficient effect, energy structure effect, energy intensity effect, industrial structure effect and economic scale effect, respectively.

The total effect of energy-related carbon emissions in productive sector is as follows:

$$C_1 = \Delta C_{1f_{ij}} + \Delta C_{1m_{ij}} + \Delta C_{1d_i} + \Delta C_{1s_i} + \Delta C_{1g} \quad (11)$$

Model for decomposition of factors affecting energy-related carbon emissions from household sector

The energy-related carbon emissions from household sector is not only on basis of population size, but also is influenced by population structure (urban or rural). Because Guangxi is at the stage of rapid urbanization with natural growth of the population has been well controlled by family planning, the urbanization plays an increasingly significant role in energy-related energy carbon emissions from household sector. In this research, the influence of population structure (urban or rural) and population size, energy structure and source on energy-related carbon emissions from household sector are all considered, and the decomposition model for household energy-related carbon emissions is as follows:

$$C_2 = \sum_{i=4}^{5}\sum_{j=1}^{18} \left(\frac{C_{2ij}}{E_{2ij}} \cdot \frac{E_{2ij}}{E_{2i}} \cdot \frac{E_{2i}}{P_i} \cdot \frac{P_i}{P} \cdot P\right) \quad (12)$$

where C_{2ij} is the energy-related carbon emissions from household sector of the energy j from population of type i (urban or rural); E_{2ij} is the consumption of energy j from population of type i; E_{2i} is the total consumption of energy from the population of type i; P_i is the population of type of i; P is total population of Guangxi.

Assuming that

$$f_{2ij} = \frac{C_{2ij}}{E_{2ij}}, \quad m_{2ij} = \frac{E_{2ij}}{E_{2i}} \quad d_{2i} = \frac{E_{2i}}{P_i} \quad s_{2i} = \frac{P_i}{P} \quad p = P$$

the contributions of carbon emissions made by different factors from household sector can be concluded as follows:

$$\Delta C_{2f_{ij}} = \sum_{i=4}^{5}\sum_{j=1}^{18} \beta \ln \frac{F_{2ij}{}^{T}}{F_{2ij}{}^{0}} \quad (13)$$

$$\Delta C_{2m_{ij}} = \sum_{i=4}^{5}\sum_{j=1}^{18} \beta \ln \frac{M_{2ij}{}^{T}}{M_{2ij}{}^{0}} \quad (14)$$

$$\Delta C_{2d_{i}} = \sum_{i=4}^{5}\sum_{j=1}^{18} \beta \ln \frac{D_{2i}{}^{T}}{D_{2i}{}^{0}} \quad (15)$$

$$\Delta C_{2s_{i}} = \sum_{i=4}^{5}\sum_{j=1}^{18} \beta \ln \frac{S_{2i}{}^{T}}{S_{2i}{}^{0}} \quad (16)$$

$$\Delta C_{2P} = \sum_{i=4}^{5}\sum_{j=1}^{18} \beta \ln \frac{P^{T}}{P^{0}} \quad (17)$$

where $\beta = \frac{C_{ij}{}^{T} - C_{ij}{}^{0}}{\ln C_{ij}{}^{T} - \ln C_{ij}{}^{0}}$, $\varDelta C_{2fij}$、$\varDelta C_{2mij}$、$\varDelta C_{2di}$、$\varDelta C_{2si}$ and C_{2p} represent effect of carbon emission coefficient, energy structure effect, energy intensity effect, population structure effect and economic scale effect in household sector, respectively.

$$C_2 = \Delta C_{2f_{ij}} + \Delta C_{2m_{ij}} + \Delta C_{2d_i} + \Delta C_{2s_i} + \Delta C_{2p} \quad (18)$$

According to equations (2), (11) and (18), the comprehensive decomposition model of carbon emissions can be concluded as follows:

$$C = C_1 + C_2 = \Delta C_{1f_{ij}} + \Delta C_{1m_{ij}} + \Delta C_{1d_i} + \Delta C_{1s_i} + \Delta C_{1g}$$
$$+ \Delta C_{2f_{ij}} + \Delta C_{2m_{ij}} + \Delta C_{2d_i} + \Delta C_{2s_i} + \Delta C_{2p} \quad (19).$$

In practice, the coefficient of carbon emissions from different energies are generally treated as constant. It can be concluded that $\varDelta C_f = \varDelta C_{1fij} = \varDelta C_{2fij} = 0$. Equation (19) can be simplified as follows:

$$C = C_{1m_{ij}} + \Delta C_{1d_i} + \Delta C_{1s_i} + \Delta C_{1g} + \Delta C_{2m_{ij}}$$
$$+ \Delta C_{2d_i} + \Delta C_{2s_i} + \Delta C_{2p} \quad (20).$$

Data sources and processing

Except of hydropower, the rest data (Table 2 and Table 3) are all from Guangxi Energy Balance Sheet in China Energy Statistical Yearbook (1996-2011) and the data of hydropower, economy and population data (Table 4) are from Guangxi Statistical Yearbook (1996-2011). The consumptions of hydropower have been

Table 2. Energy type and consumption in Guangxi during 1995-2010 (10^4 ton standard coal equivalent)

Year	Raw Coal	Washed Clean Coal	Other Washed Coal	Briquettes	Coke	Coke-oven Gas	Other Gas	Crude Oil	Gasoline
1995	1592.51	6.93	1.26	0.00	178.89	1.51	1.08	0.13	60.80
1996	1593.18	12.36	1.07	2.82	159.16	1.45	0.66	0.19	72.86
1997	1448.29	2.87	1.03	15.39	163.15	1.72	0.92	0.20	65.54
1998	1420.73	4.21	1.43	0.00	161.75	1.72	0.93	0.27	87.46
1999	1440.67	2.06	0.60	0.00	157.19	1.56	0.96	1.73	95.04
2000	1543.16	2.57	0.41	0.00	154.07	1.43	1.01	0.40	96.92
2001	1559.57	2.96	0.60	0.00	159.55	1.66	1.03	4.46	111.24
2002	1435.33	7.20	0.11	0.00	172.08	1.77	1.21	5.00	124.14
2003	1699.16	19.13	0.72	0.01	190.34	2.31	12.17	0.46	171.71
2004	2145.70	43.25	1.24	1.24	190.45	3.68	18.96	1.41	189.81
2005	2402.65	40.73	0.78	0.12	225.02	3.68	38.02	0.14	215.53
2006	2688.23	18.69	0.80	7.36	438.35	6.15	29.70	0.00	270.22
2007	3105.33	28.80	2.73	9.13	505.54	6.39	31.02	0.34	290.90
2008	2973.25	33.03	1.81	9.41	563.44	7.84	35.90	0.00	297.22
2009	3327.90	29.97	1.24	10.66	609.92	11.46	44.25	0.00	318.23
2010	3921.97	35.78	6.63	18.66	662.56	9.97	61.15	0.00	364.44

Table 2. Cont.

Year	Kerosene	Diesel Oil	Fuel Oil	Liquefied Petroleum Gas	Refinery Gas	Natural Gas	Other Petroleum Products	Other Coking Products	Hydropower	Total
1995	8.24	105.54	19.39	27.24	1.62	0.00	1.43	3.38	526.96	2536.90
1996	7.89	101.25	16.59	38.71	2.15	0.00	1.55	3.76	499.03	2514.68
1997	4.91	106.76	12.87	44.86	2.25	0.00	1.19	2.85	587.43	2462.23
1998	5.28	149.08	14.84	51.36	2.84	0.00	1.94	3.44	540.72	2448.01
1999	5.52	146.72	10.46	59.59	2.75	0.00	11.78	3.44	504.22	2444.29
2000	5.58	214.83	10.96	60.46	3.46	0.00	12.86	3.34	528.32	2639.78
2001	17.11	259.52	11.63	73.71	3.25	0.00	10.22	3.34	573.21	2793.07
2002	16.44	312.52	18.50	81.02	2.97	0.00	9.75	4.04	579.93	2772.00
2003	15.35	306.68	0.43	88.30	2.92	0.00	14.67	4.53	651.15	3180.04
2004	7.43	417.69	42.33	105.33	3.03	0.03	9.52	7.75	636.24	3825.09
2005	10.30	476.36	47.09	133.20	2.88	1.49	19.86	14.14	857.31	4489.31
2006	0.00	486.54	34.39	155.38	3.03	1.62	21.98	0.00	1065.88	5228.33
2007	0.40	545.33	29.79	162.24	3.22	1.79	29.40	0.00	1157.58	5909.92
2008	23.62	518.06	14.18	166.44	2.77	1.35	16.11	4.01	1730.91	6399.34
2009	0.13	602.67	10.54	173.09	3.32	1.61	13.70	10.58	1556.24	6725.52
2010	4.02	644.58	49.49	179.28	16.04	2.43	31.56	7.04	1519.53	7535.13

converted into consumptions in different sectors as per related ratios. Meanwhile, in order to eliminate the effect of price changes, this study converted the GDP at current price to the GDP at constant price in 2005 A.D. (Table 2 and Table 3).

Results and Discussion

As shown in Table 5, the energy-related carbon emissions in Guangxi increased from 1520.78×10^4 tC (ton of Carbon) to 4403.99×10^4 tC during 1995-2010. It is obvious that the energy-related carbon emissions grew by 189.59% in 15 years and the increase rate achieved as high as 7.35% annually.

The energy-related carbon emissions from three industries of productive sectors (primary industry, secondary industry and tertiary industry) and the consumed energies from household sectors were all increasing during 1995-2010. Specifically, the energies enhanced from 11.13×10^4 tC, 1 385.71×10^4 tC, 88.17×10^4 tC, 31.78×10^4 tC and 3.99×10^4 tC to 35.14×10^4 tC, 3 658.9×10^4 tC, 553.44×10^4 tC, 118.24×10^4 tC and 38.26×10^4 tC, respectively, and the increase rates averaged 7.97%, 6.69%, 13.03%, 9.15% and 16.27%, accordingly. Although the largest carbon emissions are from secondary industry, its increase rate is much slower compared with others and its proportion is decreasing. The proportion of consumed energies of secondary industry declined from 91.12% in 1995 to 81.68% in 2002 and maintained at 82% thereafter. In secondary industry, end-use in industry and thermal power plants account for most carbon

Table 3. Energy consumption by sectors in Guangxi during 1995-2010 (10^4 ton standard coal equivalent)

Year	Productive								Household (End-use)	
		Secondary Industry				Tertiary Industry (End-use)				
	Primary Industry	Industry (End-use)	Thermal Power production	Heat Power production	Construction (End-use)	Transport, Storage and Posts	Wholesale, Retail Trade And Hotel, Restaurants	Others	Urban	Rural
1995	37.8	1726.7	450.5	0.0	10.2	106.6	21.1	42.2	105.0	36.8
1996	42.3	1662.3	473.9	0.0	8.5	105.0	23.8	45.9	114.8	38.2
1997	36.1	1662.4	414.2	0.0	7.6	105.1	27.1	31.0	130.4	48.2
1998	40.3	1581.1	433.0	0.0	7.1	151.1	30.8	36.6	124.9	43.0
1999	41.5	1589.9	407.3	0.0	7.0	149.9	31.6	39.0	130.2	47.9
2000	39.8	1594.6	490.4	26.9	7.0	224.4	31.0	37.7	137.6	50.5
2001	47.7	1659.5	493.9	22.6	3.7	270.5	41.8	40.4	153.9	59.1
2002	50.7	1555.3	509.1	27.8	5.2	315.8	41.3	46.7	161.5	58.6
2003	41.9	1814.2	594.6	26.2	11.1	337.6	51.1	56.3	184.5	62.6
2004	62.8	1984.1	932.2	38.2	19.2	387.7	72.0	79.7	183.8	65.5
2005	69.7	2347.2	1028.0	82.1	26.3	451.0	80.1	103.8	215.6	85.5
2006	80.8	2836.2	1066.8	97.7	38.0	529.6	107.4	101.9	261.0	109.0
2007	94.2	3156.5	1265.4	127.6	36.4	580.5	114.6	128.2	281.3	125.1
2008	84.8	3613.4	1093.7	180.0	27.3	603.6	133.3	158.2	342.6	162.5
2009	82.0	3756.0	1307.0	75.3	28.4	680.1	137.7	160.0	342.3	156.7
2010	91.7	3881.1	1681.0	279.4	21.7	740.3	147.6	167.4	355.0	170.0

Table A3. GDP, population and constitutions in Guangxi during 1995-2010

Year	GDP(2005=100；100 Million Yuan)			As Percentage of GDP(%)			Population （10000 persons）			As Percentage of Total Population (%)	
	GDP	Primary Industry	Secondary Industry	GDP	Primary Industry	Secondary Industry	Total	Urban	Rural	Urban	Rural
1995	1588.83	480.77	568.52	100	30.3	35.8	4543	838	3705	18.45	81.55
1996	1721.23	542.23	595.44	100	31.5	34.6	4589	871	3718	18.98	81.02
1997	1859.73	596.36	628.43	100	32.1	33.8	4633	885	3748	19.10	80.90
1998	2045.71	627.96	714.22	100	30.7	34.9	4675	1020	3655	21.82	78.18
1999	2209.36	636.24	764.70	100	28.8	34.6	4713	1080	3633	22.92	77.08
2000	2383.90	638.80	839.81	100	26.8	35.2	4751	1337	3414	28.15	71.85
2001	2581.77	652.81	873.50	100	25.3	33.8	4788	1350	3438	28.20	71.80
2002	2855.43	681.11	958.20	100	23.9	33.6	4822	1365	3457	28.30	71.70
2003	3146.69	734.81	1097.65	100	23.4	34.9	4857	1411	3446	29.06	70.94
2004	3518.00	838.01	1284.55	100	23.8	36.5	4889	1550	3339	31.70	68.30
2005	3984.10	912.50	1510.68	100	22.9	37.9	4925	1567	3093	33.62	66.38
2006	4524.00	984.15	1790.63	100	21.8	39.6	4961	1635	3084	34.64	65.36
2007	5205.61	1109.66	2168.00	100	21.3	41.6	5002	1728	3040	36.24	63.76
2008	5872.24	1215.89	2540.71	100	20.7	43.3	5049	1838	2978	38.16	61.84
2009	6690.90	1257.69	2915.98	100	18.8	43.6	5092	1904	2952	39.20	60.80
2010	7643.78	1337.93	3603.64	100	17.5	47.1	5159	1849	2761	40.11	59.89

emissions. In addition, transportation is the largest driver for carbon emissions in tertiary industry. Moreover, carbon emissions from urban population far more than rural population in household sector during 1995-2010. The primary industry and rural population only account for a low proportion of the carbon emissions during 1995-2010. It is clearly the secondary industry, especially thermal power plants and heat power production, should be the potentiality of reduction of carbon emissions. Furthermore, the carbon emissions from transport sector and urban population should also be considered.

GDP of Guangxi grew from 158.883 billion Yuan in 1995 to 764.378 billion Yuan in 2010 and annual increase rate achieved as high as 11.87% (Fig. 3). The annual increase rate of carbon emissions is lower by 4.52% compared with that of GDP during the same period.

Carbon emissions in Guangxi are significantly influenced by economic development, industrial structure, energy structure and intensity. As shown in Fig. 3, influenced by Asian Financial Crisis (1996-2000), Guangxi economy developed

Table 5. Estimation results of energy-related carbon emissions in Guangxi / (10^4 t)

Year	Productive Sector										Household sector			Total Carbon Emissions
	Primary Industry	Secondary Industry					Tertiary Industry							
		Industry (End-use)	Power	Heat	Construction	Total	Transport etc.	Wholesale etc.	Others	Total	Urban	Rural	Total	
1995	11.13	1036.87	345.76	0.00	3.08	1385.71	61.75	8.28	18.14	88.17	31.78	3.99	35.77	1520.78
1996	13.51	1001.41	364.74	0.00	2.71	1368.86	59.54	9.98	22.19	91.71	39.36	5.68	45.05	1519.13
1997	8.80	944.74	319.08	0.00	2.81	1266.62	59.31	10.97	8.89	79.17	45.00	10.31	55.31	1409.91
1998	11.98	917.22	333.69	0.00	2.97	1253.87	87.05	12.39	11.27	110.70	38.58	6.06	44.64	1421.20
1999	12.95	946.72	313.54	0.00	3.09	1263.36	86.27	13.04	13.48	112.79	42.35	8.57	50.93	1440.03
2000	11.02	937.65	378.10	20.76	3.26	1339.76	129.36	13.14	12.47	154.97	44.10	9.09	53.19	1558.94
2001	13.92	967.23	380.87	17.45	0.92	1366.47	155.53	18.55	10.71	184.80	49.93	10.85	60.79	1625.97
2002	14.40	883.27	392.55	21.47	1.02	1298.32	182.17	18.02	12.14	212.33	54.27	10.27	64.54	1589.59
2003	10.79	1037.78	458.60	20.17	3.62	1520.17	194.19	22.02	15.77	231.98	63.45	12.00	75.45	1838.40
2004	24.80	1157.66	719.06	29.48	8.71	1914.91	224.71	34.29	28.05	287.05	69.16	15.59	84.75	2311.51
2005	27.32	1296.68	792.44	63.37	10.72	2163.20	261.22	42.28	30.36	333.85	74.61	18.64	93.25	2617.62
2006	32.35	1584.08	822.27	74.99	16.52	2497.85	306.56	48.81	30.68	386.05	89.41	23.15	112.56	3028.81
2007	39.83	1785.08	970.52	98.09	16.44	2870.13	337.00	53.04	46.97	437.01	98.36	29.42	127.78	3474.75
2008	25.62	1817.59	838.12	138.49	9.87	2804.06	348.72	56.02	50.32	455.06	101.34	26.55	127.89	3412.63
2009	25.47	2041.38	1003.67	57.63	10.38	3113.06	393.32	60.26	54.08	507.67	105.46	27.50	132.96	3779.16
2010	35.14	2152.47	1287.86	215.30	3.26	3658.90	425.62	67.66	60.17	553.44	118.24	38.26	156.50	4403.99

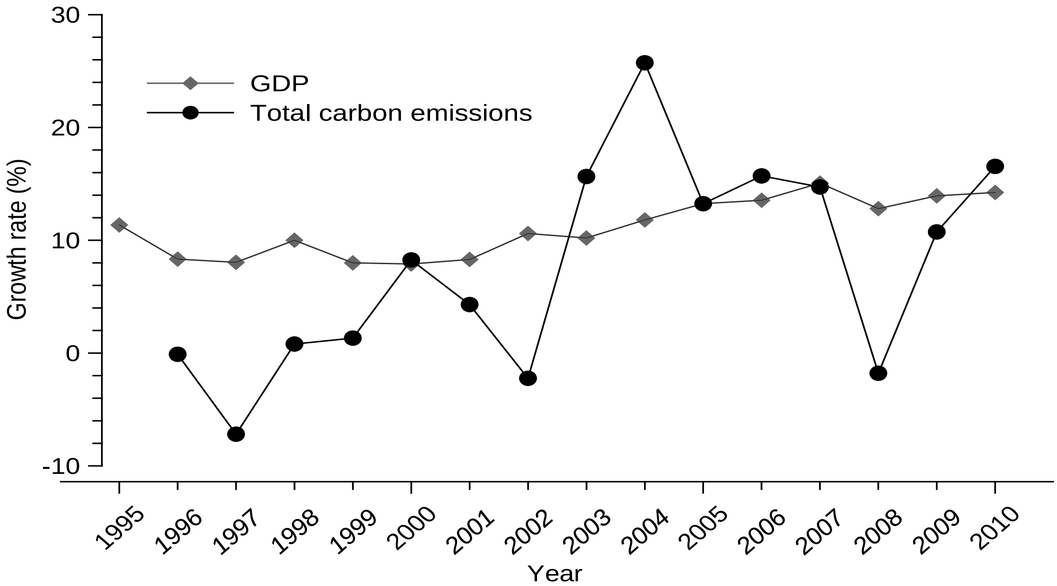

Fig.3 Growth rate of GDP and total carbon emissions

slowly and met deflation. The economic proportion of secondary industry declined substantially, hitting its lowest level in 1997.

However, the proportion of secondary industry began to increase and achieved the maximum in 2000 for great investment in infrastructure construction. Consequently, energy-related carbon emission kept increasing and reached a peak at 2000. During the 10^{th} Five-year Plan (2001-2005), Guangxi's GDP achieved an high annual increase rate more than 10%, but the proportion of secondary industry dropped at early period, leading to successive decline of carbon emissions and minimal emissions in 2002. Since 2002, the proportion of secondary industry increased fast, resulting in more carbon emissions. It is notable that carbon emissions achieved its maximum in 2004, and then carbon emissions reduced dramatically under influence of high crude oil price and macro-control of high-energy consuming industries, including steel and cement industries.

During the 11^{th} Five-year Plan (2006-2010), economy grew much fast with an increase rate of 13%-15%. Although influenced by financial crisis in 2008, Guangxi's economy still kept a considerable increase rate at 12.8% due to the economic stimulus plan led by governments. During the whole period of the 11th Five-year Plan, carbon emissions increased slowly. Generally, Guangxi's carbon emissions showed a U-shaped curve during 2006-2010. After all, carbon emissions in Guangxi was mainly influenced by economic aggregate and industrial structure in the 9th Five-year Plan, by economic aggregate, industrial structure and consumption intensity of energy in the 10th Five-year Plan, and by economic aggregate and carbon emissions from secondary industry during the 11th Five-year Plan.

The hydropower in Guangxi took up 16.3%-27.05% of total energy, playing a key role in carbon reduction. In Guangxi, carbon emissions changed significantly in 1997, 2004 and 2008. Specifically, carbon emissions achieved the minimum in 1997 and 2008, and the maximum in 2004. It is probably due to a high proportion of hydropower in Guangxi's energy consumption in 1997 and 2008, and a low proportion of hydropower in 2008.

As shown in Table 6 and Table 7, total contribution value of productive sector and household sector increased from -31.74×10^4 tC in 1996 to 2 827.86×10^4 tC in 2010. In general, according to influential factors of energy consumption and carbon emissions made by productive sector and household sector (Fig.4), the comprehensive effect of carbon emissions in Guangxi can be classified into two stages in 1996-2002, as follows: The first stage is 1996-2002 when comprehensive effects of influential factors of carbon emission were not so significant and the comprehensive effects of carbon emissions from household sector became the dominant driver of carbon emissions. In this period, the effect sizes of both productive sector and household sector were lower. Furthermore, household sector showed positive effect, but productive sector showed negative effect except for 2001. Specifically, in the early period, the positive effect of household sector was lower compared with the negative effect of productive sector and the comprehensive effect of carbon emissions showed a lower negative effect. In later period, however, the positive effect of household sector exceeded negative effect of productive sector and the comprehensive effect of carbon emission showed a lower positive effect. The second stage is 2003-2010 when comprehensive effect of carbon emission was higher and even grew gradually. Specifically, carbon emission of productive and household sectors both showed positive effect, and the effect of productive sector was significantly higher than that of household sector. Hence, productive sector became the dominant factor of carbon emissions from energy consumption. In 2010, the effect of productive sector took up 95.57% which was higher than that of household sector.

These indicated that the contribution of carbon emissions by productive and household sectors differs in varied economic stages. During 1996-2002, Guangxi was in deflation when household sector was the major source of carbon emissions. However, Guangxi' economy went out of deflation and the economy growth rate increased fast since 2003. In this period, the effect of productive sector was significantly higher than that of household sector and productive sector was the dominant driver of carbon emissions.

In 1996-2010, four decomposed factors of carbon emissions in productive sector made contribution from -59.22 to 2702.67 tC. In detail, China's economy was influenced by deflation in 1996-2002, when the effect of carbon emissions was -176.51～34.14 tC. The negative effect achieved the maximum in 1997 for influence of Asian Financial Crisis. Due to the fast growth of economy, carbon emissions from productive sector in Guangxi showed a positive effect during 2003-2010, and the carbon emissions increased significantly from 233.17 tC in 2003 to 2702.67 tC in 2010.

During research period, economic scale effect and energy intensity effect had the most significant effect. Specifically, economic scale effect showed a high positive effect, but the energy intensity effect showed a high negative effect, followed by industrial structure effect and energy structure effect (Fig. 5).

(1) Economic scale effect

During 1995-2010, carbon emissions from productive sector enhanced from 118.28×10^4 to 4057.22×10^4 tC (Fig. 6). In detail, secondary industry accounted for most of the carbon emissions, form 110.12×10^4 in 1995 to 3650.78×10^4 tC in 2010. Although the carbon emissions proportion of secondary industry was decreasing since 1995 (93.10%), it always kept higher than 89.5%. The carbon emissions proportion of tertiary industry maintained increasing from 6.07% in 1995 to 9.14% in 2010, but carbon emissions proportion of primary industry only tended to be 0.5%-0.9%. During the

Table 6. Contribution of each decomposed factor to energy-related carbon emissions in Guangxi during 1995-2010 (10^4tC)

Year	⊿C_{1m}	⊿C_{1d}	⊿C_{1s}	⊿C_{1g}	⊿C_{2m}	⊿C_{2d}	C_{2ps}	⊿C_{2p}	⊿C_1	⊿C_2	⊿C
1996	10.10	-95.37	-92.23	118.28	24.17	1.93	0.98	0.40	-59.22	27.48	-31.74
1997	-62.63	-216.06	-120.96	223.14	11.03	6.77	1.17	0.77	-176.51	19.74	-156.77
1998	-29.40	-408.60	-77.15	360.67	9.36	-0.02	5.46	1.09	-154.47	15.90	-138.57
1999	-6.99	-523.69	-83.28	472.03	6.35	0.11	7.23	1.46	-141.92	15.16	-126.77
2000	0.98	-573.30	-55.80	602.82	24.57	-4.91	14.36	1.83	-25.29	35.84	10.55
2001	-8.90	-588.27	-101.99	733.31	7.99	-0.40	15.16	2.27	34.14	25.02	59.16
2002	-23.02	-748.74	-104.55	870.33	52.11	-0.09	16.11	2.55	-5.98	70.67	64.70
2003	-20.31	-782.33	-56.01	1091.81	18.57	4.44	18.00	3.04	233.17	44.05	277.22
2004	45.88	-795.23	8.63	1435.85	104.69	1.27	22.41	3.56	695.13	131.94	827.07
2005	-11.53	-844.58	75.68	1773.76	24.57	10.43	22.82	4.11	993.32	61.93	1055.25
2006	-19.44	-944.88	162.82	2185.72	28.30	21.12	26.84	5.00	1384.22	81.26	1465.47
2007	6.59	-1146.72	272.90	2680.69	34.48	25.88	30.27	5.86	1813.46	96.49	1909.96
2008	-198.63	-1312.25	341.42	2916.21	21.82	34.51	33.77	6.46	1746.75	96.57	1843.32
2009	-89.60	-1597.61	389.66	3404.94	25.54	33.09	35.86	7.14	2107.38	101.64	2209.02
2010	-0.28	-1950.14	595.88	4057.22	37.53	43.90	34.94	8.82	2702.67	125.19	2827.86

Table 7. Contribution rate of each decomposed factor to energy-related carbon emission（⊿C_i/abs(⊿C)*100, % ）

Year	⊿C_{1m}	⊿C_{1d}	⊿C_{1s}	⊿C_{1g}	⊿C_{2m}	⊿C_{2d}	C_{2ps}	⊿C_{2p}	⊿C_1	⊿C_2	⊿C
1996	31.82	-300.47	-290.58	372.65	76.15	6.08	3.08	1.27	-186.57	86.57	-100.00
1997	-39.95	-137.82	-77.16	142.33	7.04	4.32	0.75	0.49	-112.59	12.59	-100.00
1998	-21.21	-294.86	-55.68	260.28	6.76	-0.02	3.94	0.79	-111.47	11.47	-100.00
1999	-5.51	-413.11	-65.69	372.36	5.01	0.09	5.71	1.15	-111.95	11.95	-100.00
2000	9.32	-5432.27	-528.70	5712.01	232.84	-46.52	136.02	17.30	-239.64	339.64	100.00
2001	-15.05	-994.37	-172.39	1239.53	13.51	-0.68	25.62	3.83	57.71	42.29	100.00
2002	-35.58	-1157.26	-161.59	1345.20	80.54	-0.14	24.89	3.94	-9.24	109.24	100.00
2003	-7.33	-282.21	-20.20	393.85	6.70	1.60	6.49	1.10	84.11	15.89	100.00
2004	5.55	-96.15	1.04	173.61	12.66	0.15	2.71	0.43	84.05	15.95	100.00
2005	-1.09	-80.04	7.17	168.09	2.33	0.99	2.16	0.39	94.13	5.87	100.00
2006	-1.33	-64.48	11.11	149.15	1.93	1.44	1.83	0.34	94.46	5.54	100.00
2007	0.34	-60.04	14.29	140.35	1.81	1.36	1.58	0.31	94.95	5.05	100.00
2008	-10.78	-71.19	18.52	158.20	1.18	1.87	1.83	0.35	94.76	5.24	100.00
2009	-4.06	-72.32	17.64	154.14	1.16	1.50	1.62	0.32	95.40	4.60	100.00
2010	-0.01	-68.96	21.07	143.47	1.33	1.55	1.24	0.31	95.57	4.43	100.00

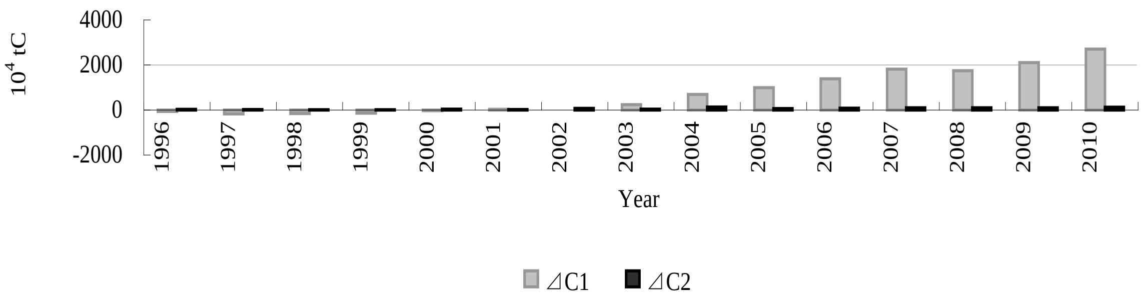

Fig.4 The contribution of productive and household sector

study period, the contribution rate of economic output always kept higher than 100%. The contribution rate of economic output was lower than 400% during 1996-1999, but suddenly shot up to 5 712.01% in 2000 which was the highest in the period. In 2001 and 2002, the rate dropped to 1 300% again and maintained lower than 400% since 2003. It's indicated that the effect of carbon emissions from economic output was declining since 2000. It is notable that economic development in Guangxi promoted increase of carbon emissions. Therefore, it is important to coordinate the relation between economic development and energy consumption.

In the study period, the structure of energy in Guangxi tended to be fluctuant. For example, the contribution of energy structure effect in 1996 was the highest at 31.82 tC; in 2000 and 2004, the contribution was at peak, namely 9.32 and 5.554 tC; in 1997, 2002 and 2008, the contribution was at trough, namely, -39.95, -35.58 and -10.78 tC.

The energy structure effect is significantly

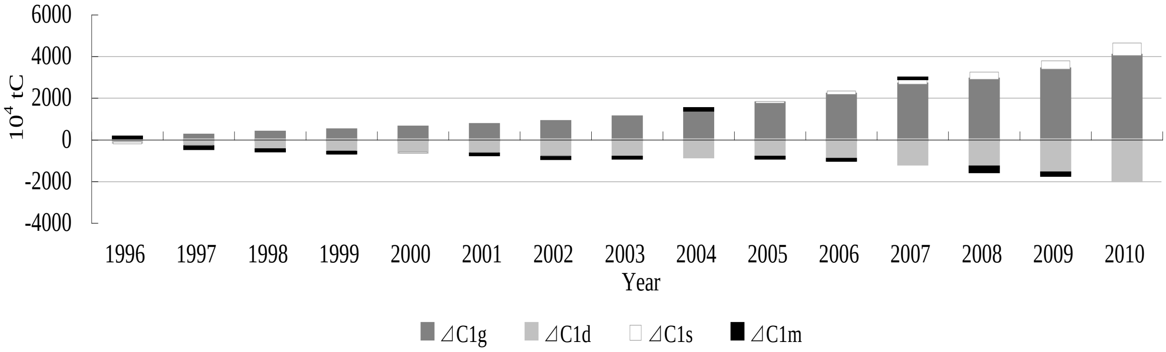

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Fig.5 The contribution of each decomposition factors for productive sector

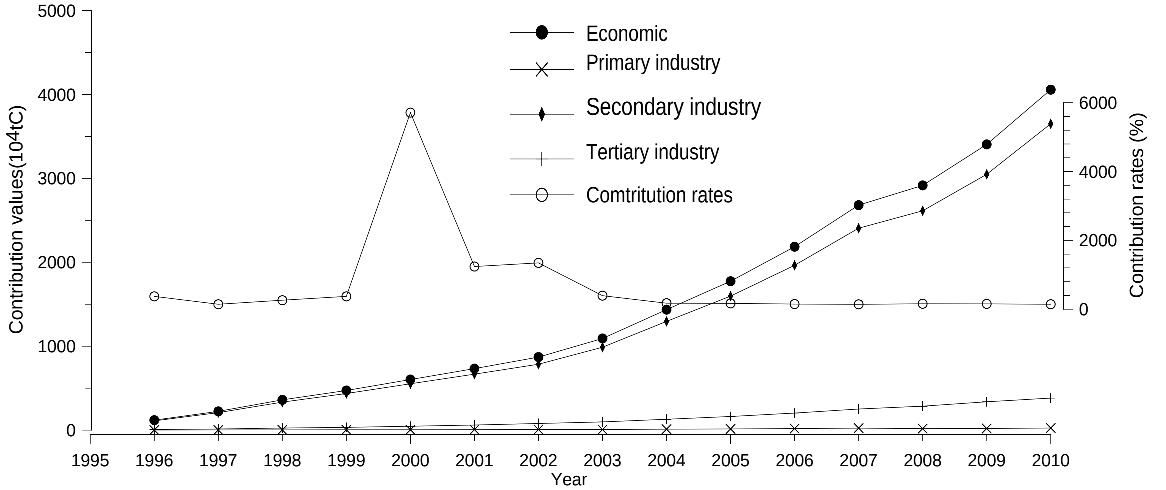

Fig.6 Contribution of economic output effect from 1996 to 2009

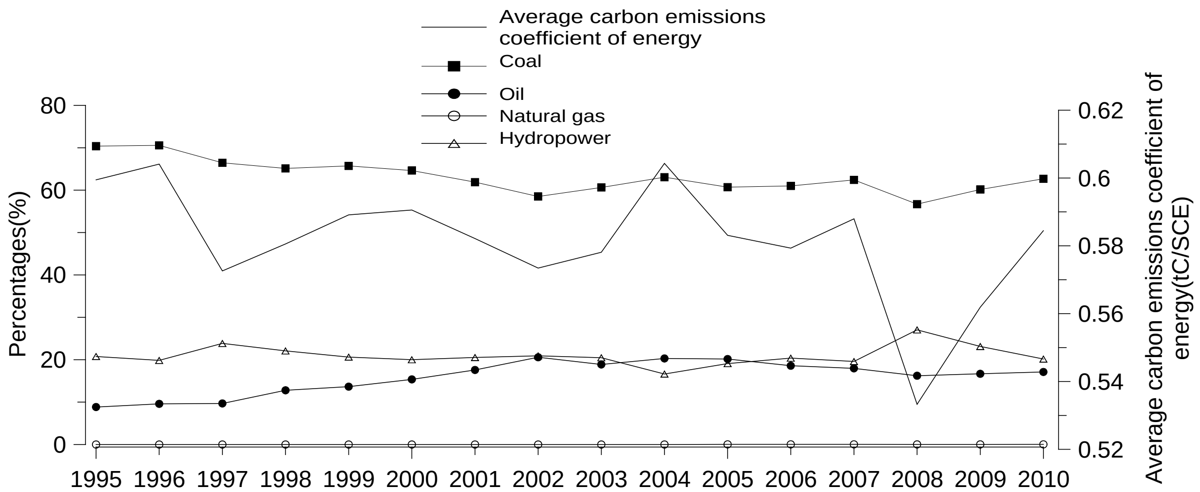

Fig.7 Energy mix and average carbon emission coefficients of energy

affected by characters of energy structure in Guangxi. As shown in Fig. 7, the peaks included the values in 1996, 2000 and 2004, and the trough included the values in 1997, 2002 and 2008, corresponding to energy effects in Guangxi. Average coefficient of carbon emissions is determined by energy structure. In research period, the energy structure effect in Guangxi was mainly influenced by structure of coal, oil and hydropower, of which the last two aspects had the most significant effect. As for natural gas, the consumed proportion was lower than 0.04%, and its contribution can be neglected. It can be found that the curve of hydropower showed two peaks in 1997 and 2008 and a trough in 2004, corresponding to coefficients of average carbon emissions from energies. In addition, the curve of coal was similar to coefficient of average carbon emissions from energy.

In general, Guangxi relied on coal as its primary energy during the research period, but hydropower was crucial for carbon emissions reduction.

As shown in Table 6 and Table 7, the energy intensity effect made the greatest contribution to reduce carbon emissions in productive sector of Guangxi during the study period, which contributed carbon emission -1.25×10^9 t. Energy efficiency of Guangxi was improved during the study period. In addition, the reduction energy intensity effect on carbon emissions from productive sector kept increase from 1996 to 2010, and tended to speed up after 2006 due to the policy of energy saving and emission reduction.

The contribution made by energy intensity effect on carbon emissions reduction was higher before 2000 in Guangxi. The contribution achieved -5432.27% in 2000, and then kept -60%--80% since 2004. This indicated that the energy intensity effect on carbon emission reduction in Guangxi declined in later period (Fig. 8).

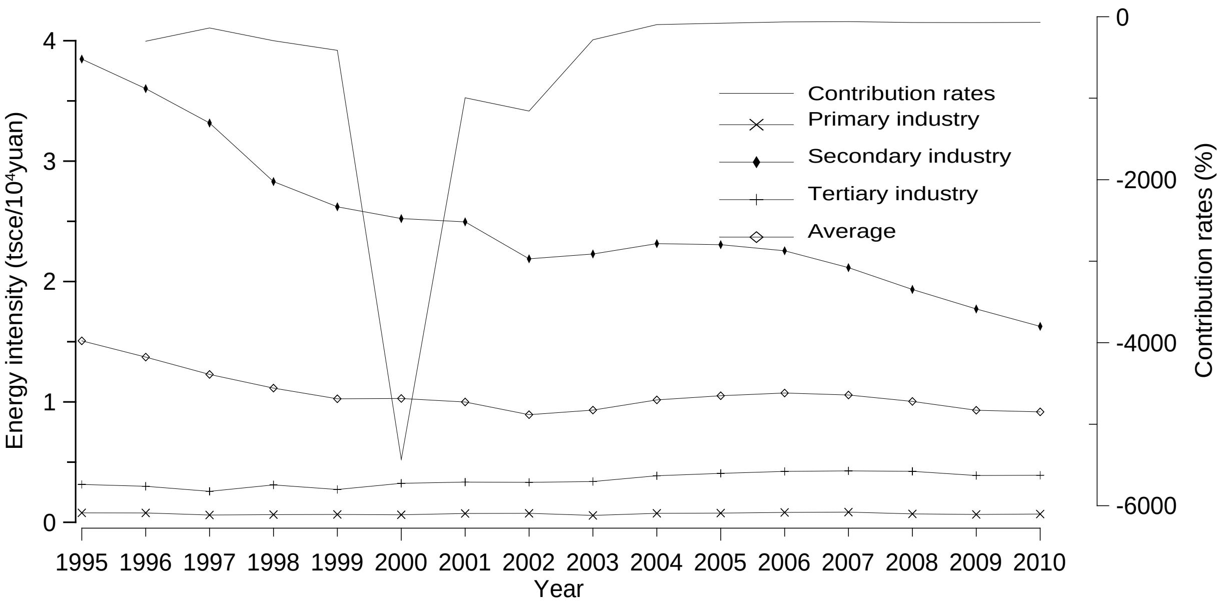

Fig.8 Changes of energy intensity and contributions rates of energy intensity effect

The reduction of energy intensity in Guangxi is contributed by the secondary industry. During research period, the energy intensity of primary and secondary industries changed little. However, the energy intensity of secondary industry decreased from 3.8476 to 1.6270 tsce/10^4 Yuan, leading to the decrease of average intensity of production energy in Guangxi from 1.5075 to 0.9171 tsce/10^4 Yuan. Compared with provinces in Eastern China[15], the energy intensity of productive sector in Guangxi was higher, meaning Guangxi has more potential to cut carbon emissions.

Meanwhile, the energy intensity of secondary industry is significantly higher than that of tertiary industry. Hence, it is possible to reduce energy intensity by developing low-carbon tertiary industry and reducing the proportion of carbon-intensive secondary industry in Guangxi.

During 1996-2010, the effects of industrial structure in Guangxi can be classified into two stages, as follows: The first stage is 1996-2003 which characterized by negative industrial structure effect, and the second stage is 2004-2010 which characterized by faster increasing positive industrial structure effect. For example, the contribution value of industrial structure was 8.63 tC in 2003 and grew to 595.88 tC in 2010, promoting the industrial structure effect only next to economic scale effect.

As shown in Fig. 9, in 1995-2003, the proportion of secondary industry in the GDP was about 33.56%-35.78%. During the same period, the proportion of primary industry in the GDP declined, but the proportion of tertiary industry grew. The adjustment of industrial structure had negative effect on carbon emissions during 1995-2003. However, the proportion of secondary industry in the GDP maintained growing, but the proportions of the others declined during 2004-2010. In addition, the carbon emissions from secondary industry exceeded that sum of other industries, probably because the rapid development of high-energy consuming industry in Guangxi. Compared with other regions in China, the proportion of tertiary industry in Guangxi is still low, indicating that it is important to develop tertiary industry and to optimize industrial structure.

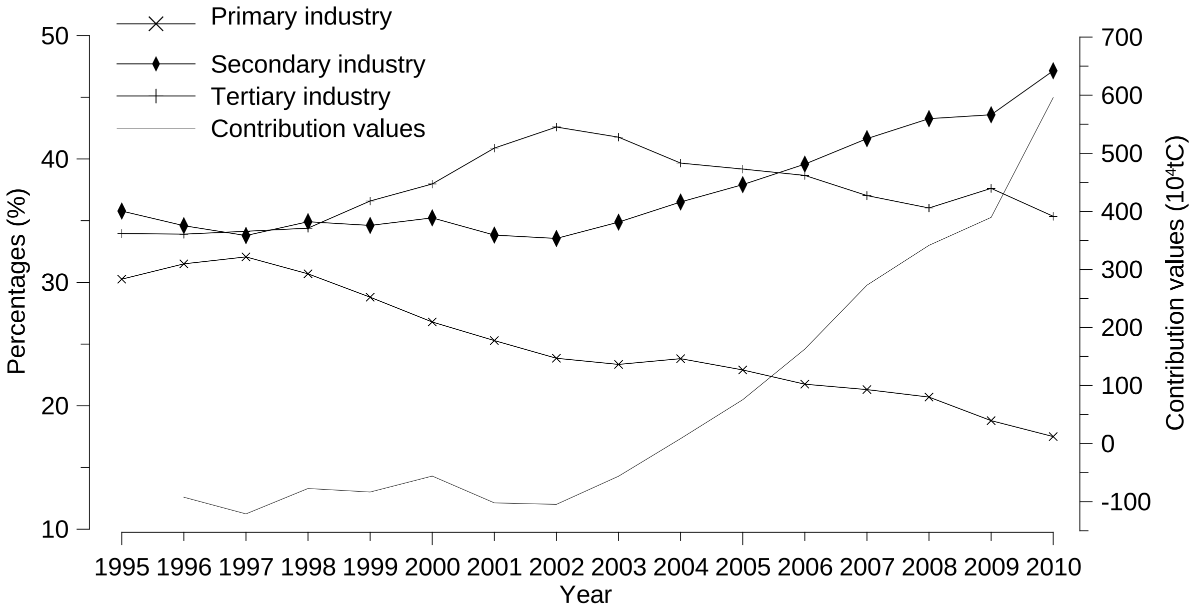

Fig.9 Changes of industrial structures and contribution of industrial structure effect

During 1996-2010, the comprehensive effect of four decomposed factors is positive in household sector and the contribution value increased from 27.48 to 125.19 tC. During 1996-2000, the intensity of carbon emissions decreased to the minimum in 2000. Since 2000, the energy-related carbon emissions from household sector tended to be fluctuant, but still kept growing. In detail, the carbon emissions from household sector increased from 35.84 tC in 2000 to 125.19 tC in 2010. Of all decomposed factors, effects of energy structure and population structure proved the most significant, followed by effects of energy intensity and population scale (Fig. 10).

In study period, Guangxi's population size and urbanization process led to the increase of the energy-related carbon emissions, of which the effect of the latter proves higher (Fig. 10). As a result of family planning, population increased slowly from 45.43 to 51.59 million in Guangxi with an average annual growth rate about 8.51%, reducing carbon emissions from effect of population size.

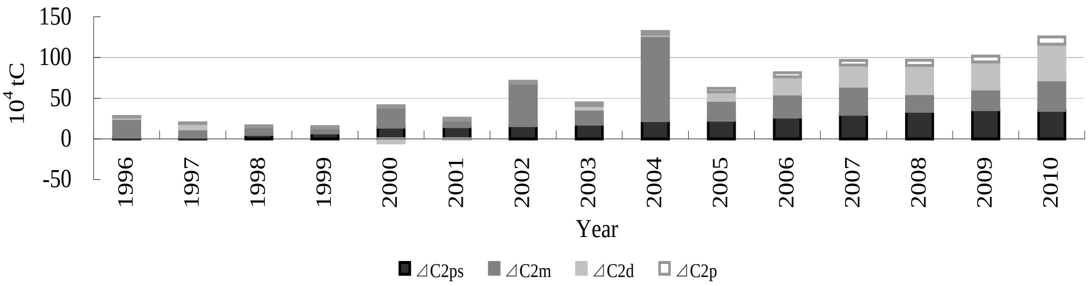

Fig.10 The contribution of each decomposition factors for household sector

As shown in Fig.10, it is obviously that the population structure effect accounted for most energy-related carbon emissions from 1996 to 2010 in Guangxi, due to the fast urbanization. During this period, urbanization rate grew from 18.45% to 40.11% in Guangxi with an average annual growth rate of 1.44%, increasing the urban population from 8.38 to 18.49 million. Consequently, numerous peasants came to secondary and tertiary industries in cities, transforming into urban way of life. However, the energy-related carbon emissions per capita urban residents far exceeded that of rural residents in China, promoting long lasting increase of carbon emissions from 1996 to 2010. Furthermore, the carbon emissions gap between urban and rural residents enlarged from 0.98×10^4 to 34.92×10^4 tC during the study period. Obviously, the population structure effect has become the dominant driver of carbon emissions in household sector in Guangxi.

(2) Effects of energy structure and intensity

Structure and intensity of energy for household sector also significantly influenced the energy-related carbon emissions from household sector. Unlike the energy structure for productive sector, the energy structure effect for household sector was proved the primary driver for carbon emissions in household sector. Although the carbon emissions of structure effect decreased from 24.17×10^4 to 6.35×10^4 tC from 1996 to 1999, the effect grew from 2000 to 2004 and reached the peak at 104.69×10^4 tC. In 2005, the effect dropped sharply to 24.57×10^4 tC and grew slowly to 37.53×10^4 tC in 2010.

Similarly, during the study period, energy intensity effect in household sector also contributed for energy-related carbon emissions in Guangxi. Specifically, energy intensity effect of household sector produced -4.91-6.77×10^4 tC during 1996-2004 due to deflation, and then the contribution increased rapidly in 2005, but stopped growing in 2009 due to financial crisis, and then the contribution shot up to 43.90×10^4 tC in 2010.

As an economically backward autonomous region with low urbanization rate, the per capita GDP of Guangxi ranks 26th among the 31 provinces and cities in China (Fig.11a). As shown in Fig.11b, the composition of Guangxi's GDP was characterized by high proportion of primary industry and low proportion of tertiary industry compared with China (Fig.11b). The proportion of secondary industry took up more than 40% meaning the development of Guangxi depended heavily on secondary industry, though the secondary industry is a dominant factor to energy-related carbon emission.

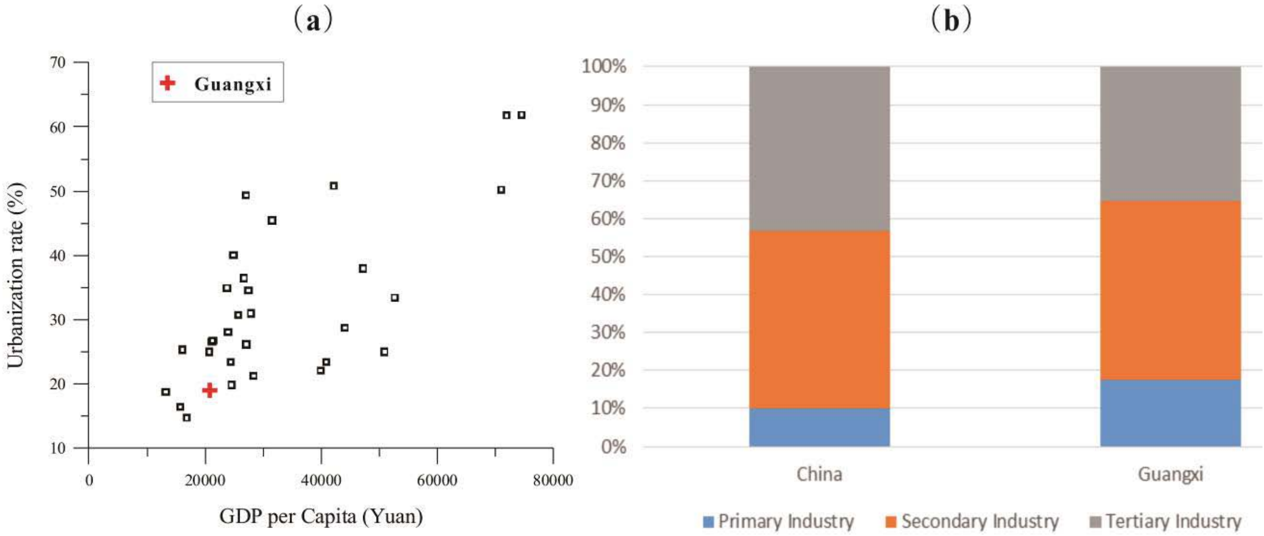

Fig.11 GDP per capita of 31 provinces and cities in China (a) and the composition of China's GDP and Guangxi's GDP in 2010 (b)

Moreover, it should be noted there were 28 state-level poverty-stricken counties of Guangxi in 2010 with 8 counties are ethnic minority autonomous counties, which accounting for 25.7% among all counties in Guangxi (Fig.12a). As shown in Fig.12b, the state-level poverty-stricken counties are characterized by both low urbanization rate and per capita GDP. According to the fourth national census in 2010, the total population in Guangxi was 46.03 million with 37.8% minority nationalities. In order to get rid of regional development inequalities, it is urgent to speed up economic development, especially for the rural and ethnic minorities areas. However, the government also faced the China's energy- and emissions-intensity targets which were expressed as ratios of energy use or total emissions to GDP.

The energy intensity effect is of the highest negative effects on carbon emission in Guangxi. The Chinese Central Government's 12th Five-year plan (2011–15) calls for a 16% reduction in energy intensity and for a 17% reduction in carbon intensity. Although the Chinese central government has promoted the energy conservation examination system throughout the country since 2007, the traditional examination system are designed for planned economy, with little regard for regional differences of economic development and industry structures. Because each province and city has been allocated mandatory targets, Guangxi may need to conform to the obligations to reducing CO_2 emissions by slowing down the economic growth rate as other developed regions.

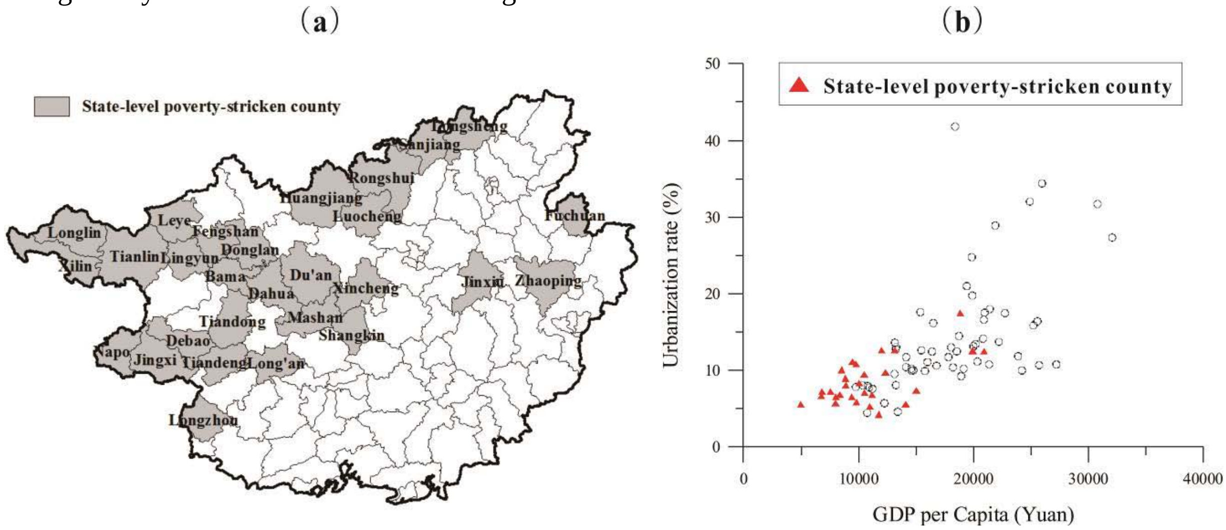

Fig.12 State-level poverty-stricken counties in Guangxi (a) and the counties' urbanization rate (b)

Conclusions

In this research, the energy-related carbon emissions from productive and household sectors in Guangxi during 1995-2010 were calculated based on statistical dada. Furthermore, improved decomposition models for energy-related carbon emissions were established by Kaya function and LMDI to study the driving and inhibiting factors which influence energy-related carbon emissions in Guangxi.

Our results showed that in 1995-2010, energy-related carbon emissions from productive and household sectors kept increasing with an average annual growth rate of 7.35%. The continuous growth of economic output is the dominant driver of energy-related carbon emission in Guangxi. Energy-related carbon emissions in Guangxi kept fast increasing that brought enormous pressure to carbon emissions reduction. However, as one of the under-developed areas in China, it is suggested that the governments of Guangxi rely on the improvement of industrial structure and energy efficiency to reduce energy-related carbon emissions rather than limiting the economic development.

The effects of energy-related carbon emissions from productive and household sector on carbon emissions were characterized by economic oscillations. In detail, household sector was the dominant driver for energy-related carbon emissions in 1996-2002, but productive sector superseded household sector in energy-related carbon emissions since 2003 for the rapid development of economy.

The effects of industrial structure resulted in significant carbon emissions in Guangxi since 2002, and then became a dominant driver for energy-related carbon emissions only next to economic scale. Therefore, more efforts should be paid to adjustment of industrial structure in Guangxi. It is possible to promote the low-carbon tertiary industry rather than the carbon-intensive second industry (e.g. steel production, cement) to reduce the energy-related carbon emissions for Guangxi.

Because the proportion of coal was essentially unchanged in energy structure for productive sector in Guangxi, the energy structure effect only played a minor role in carbon emissions reduction. Nevertheless, hydropower played an important role in carbon reduction for Guangxi. Meanwhile, the proportion of natural gas should be enhanced in energy consumption to adjust energy structure. The governments also need to develop other non-fossil energy (e.g. nuclear power, wind power, solar energy and biomass energy) to reduce energy-related carbon emissions in Guangxi.

In addition, our results also show the Guangxi's urbanization have increased energy consumption and would increase in future, because the urbanization level of Guangxi still is still insufficient. Therefore, some measures of urban planning should be highlighted, including develop low-carbon cities and buildings in future. On the other hand, progresses in low-carbon consumption can be accelerated to achieve sustainable development.

More importantly, this study highlighted the non-regional differences emissions targets based may exaggerate regional development inequalities by outsourcing the mitigation cost from developed regions to economically backward regions. Fortunately, the policy of Development Priority Zones (DPZ) which was put forward by the Chinese Central Government in the 12th Five-year Plan (2011–15), in order to harmonizing the economic growth with resource and environment. As one of the most important macro-control measure in the 12th Five-year Plan, DPZ policy is completely different from past regional planning policy by classifying different development goals for different regions based on their functions in sustainable development. According to the DPZ policy, Guangxi should pay more attention to its ecological and agricultural functions rather than industrialization. Therefore, it is believed DPZ policy provides an opportunity for Guangxi to create a pathway towards low-carbon development. However, it is still hard for Guangxi to obtain compensation without a national carbon emission trading system. The question now is how China will react when confronted with the political problems that inevitably accompany the creation of national carbon emission markets.

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