On Complete Carbon Emission of China's Industries Based on Input-Output Analysis

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Abstract This article establishes a useful analytical framework for complete carbon emission of the industries in China and then makes comparison on carbon emission among these industries based on the latest data derived from China's Input-Output Table and Energy Statistics in 2007. It is found that some industries are "invisible high-carbon" sectors by the definitions of directly-embodied coefficient and perfectly-embodied coefficient and that others have made contributions to carbon leakage by measure of importing and exporting carbon emission volume. Finally, this article provides suggestions to industrial strategies, trade policies and the comprehensive economic management policy in order to effectively achieve energy conservation and emission reduction.

Keywords input-output analysis; directly-embodied coefficient; perfectly-embodied coefficient

1 Introduction

It is well known that global warming has seriously threatened human's survival environment. This is ascribable to the carbon dioxide as a leading component in greenhouse gas. Therefore, the issue concerning reduction of greenhouse gas, especially of carbon dioxide, has attracted world-wide attention. In June 1992, the United Nations' Conference on Environment and Development approved "United Nations Framework Convention on Climate Change", appealing to ultimately limit the greenhouse atmosphere concentration at a reasonable level so as to maintain the world's sustainable development. Besides, the Kyoto protocol signed in 1997 further regulated specific objectives for developed countries as to how they implement carbon emission reduction strategies at the initial stage. China has grown to be the biggest developing country in the world, which is consistent with its numerous energy consumption and carbon emission accordingly. For instance, in 2007, China carbon dioxide discharge reached 6.72 billion tons which occupied a percentage of 24.3% in the world total amount and exceeded the record made by the US, and thereby become No.1. At the United Nations Climate Change Summit

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held in 2009, the Chinese government claimed that by 2020 carbon dioxide emissions per Gross Domestic Product would be reduced by 40% to 45% compared with 2005^[1].

Realization of the overall target of emission reduction largely depends on specific industrial policies and trade policies that are supported by scientific theories and empirical analysis. In general, carbon emission mainly originates from consumption of fossil fuel, which is further divided into direct and indirect consumption. The so-called direct consumption comes from energy consumed during direct manufacturing process of final output, while the indirect one refers to energy consumed in the process of producing intermediate product. The two types of energy consumption are accompanied by carbon discharge, which leads to concepts of direct and indirect carbon emissions. The total sum of direct and indirect carbon emissions constitutes a complete carbon emission for any end products made by all industrial sectors. As a usual rule, input-output analysis is suitable for making calculation of the complete carbon emissions.

Many literatures have analyzed carbon embodied in goods and services via input-output analysis, including [2] aiming for Japan, [3] and [4] aiming for Brazil, [5] aiming for Spain, [6] aiming for Australia, [7] aiming for Italy, [8] aiming for India. Meanwhile, in China some researchers have also concentrated attention on carbon emission individually from the angle of final consumption and embodied discharge of China in 2002 by [9], from the final demand for energy consumption in international business in 2002 by [10, 11], and from the embodied discharge of imports and exports by [12]. It should be noted that [13] examined the carbon emission between China and the US separately. Furthermore, [14] established regional carbon structural analysis model, and [15] made a comparative study between China and some developed countries from OECD by using data concerning industrial sectors and G7 as well.

The above-mentioned literature mainly focus on embodied carbon resulting from global trade and at the same time emphasize carbon release between nations in the world with the latest data in 2005. This article, however, places emphasis on comparison of carbon emission characteristics between various industries, followed by suggestions on emission reduction with the latest data deriving from the Input-Output Table of 2007.

The paper is structured as follows. Section 2 sets up an analytical framework of industrial complete-carbon emission after defining perfectly-embodied carbon coefficient, and then makes some explanations on applicable variables and data. Calculation results and empirical analysis are shown in Section 3. Finally, a conclusion and recommended suggestions are made in Section 4.

2 Methodology

2.1 Analytical framework concerning complete carbon emission of the industries

Input-output analysis can comprehensively reflects the interdependence of internal sectors in an economic system. The basic formula is described as follows

$$x = (I - A)^{-1}Y \quad (1)$$

where $X = (X_1, X_2, \dots, X_n)^T$ is the vector of total output, $Y = (E, M, con, I)$ is the vector of final demand, $E = (E_1, E_2, \dots, E_n)^T$ is the export vector, $M = (M_1, M_2, \dots, M_n)^T$ is the import vector, $con = (con_1, con_2, \dots, con_n)^T$ is the consumption vector, $I = (I_1, I_2, \dots, I_n)^T$

is the investment vector, $(I - A)^{-1} = (b_{ij})_{n \times n}$ is the Leontief inverse matrix, and b_{ij} means the consumption of sector i 's end product per unit on sector j 's final product.

Next, we define an important concept called direct carbon emission coefficient (abbreviated as DCEC) of sector k as below:

$$d_k = \frac{C_k}{x_k} = \frac{\sum \delta_i \gamma_i q_{ik}}{x_k}, \quad k = 1, 2, \dots, n \quad (2)$$

where q_{ik} refers to energy sector i 's direct energy demand of sector k in physical units, γ_i the coefficient used to convert the i th kind of energy into BiaoMei, δ_i the carbon emission coefficient of every energy, C_k the gross carbon emissions of sector k , and x_k the gross output of sector k , $d = (d_1, d_2, \dots, d_n)$ the vector of direct carbon emission coefficients.

Based on direct emission coefficient d_k and the meaning of b_{ij} , we define the second essential concept called the total carbon emission coefficient (abbreviated as TCEC) of sector k as shown below:

$$\lambda_k = \sum d_j b_{jk} \quad (3)$$

where $\lambda = (\lambda_1, \lambda_2, \dots, \lambda_n) = d(I - A)^{-1}$ is the vector of total carbon emission coefficients. As a result, the gross carbon emission is computed as:

$$c = \lambda Y = (\lambda E, \lambda M, \lambda Con, \lambda I) \quad (4)$$

where $\lambda E = \sum \lambda_i E_i$ is the gross carbon emission of the exporting sectors, $\lambda M = \sum \lambda_i M_i$ the gross carbon emission of the importing sectors, $\lambda Con = \sum \lambda_i Con_i$ the gross carbon emission of the consumption sectors, and $\lambda I = \sum \lambda_i I_i$ the gross carbon emission of the investment sectors. Thus, the net export carbon emission is computed as $NX - C = \lambda E - \lambda M$.

2.2 Data source of the Variables

According to the definitions of the above variables, they are divided into four levels such that the variables in the lower levels are computed from the variables in the higher levels as shown in Table 1. In Table 1, we also list the data sources of these variables^[16–17].

Table 1 Variables list

Variable				Data source
Grade 1	Grade 2	Grade 3	Grade 4	
			q_{ik}	China's Input-Output Table (2007) ¹
		C_k	γ_i	China's Input-Output Table (2007)
λ_i	d_j		δ_i	IPCC (2006) et al. ²
		X_k		China's Input-Output Table (2007)
	b_{jk}	A		China's Input-Output Table (2007)
E_i, M_i, con_i, I_i				China's Input-Output Table (2007)

¹China's Input-Output Table (2007) is quoted from website: <http://www.iochina.org.cn/>.

²The United Nations Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) jointly. Its main task is to assess the current state of scientific knowledge on climate change, the potential impact of climate change on society and economics, and possible countermeasures for adapting to and mitigating climate change. Up to 2006, IPCC has released four reports.

Since the carbon emission of each industry equals the consumption of BiaoMei multiplied by carbon emission coefficient and BiaoMei consumption is calculated based on average low calorific value, nine kinds of resources are chosen including coal, coke, crude oil, petrol, kerosene, diesel oil, fuel oil, natural gas and electricity when measuring energy consumed by each sector. The data of γ_i and q_{ik} comes from China's Energy Statistics Yearbook (2007). The relevant nine γ_i s and δ_i s are shown in Table 2.

Table 2 Coefficients in terms of coal for the nine kinds of energy resources

Coefficient	Coal	coke	Crude oil	Petrol	Kerosene
γ_i	0.7143	0.9714	1.4286	1.4714	1.4714
	(kg sc/kg)	(kg sc/kg)	(kg sc/kg)	(kg sc/kg)	(kg sc/kg)
δ_i (ton-coal/tsc)	0.682	0.765	0.676	0.620	0.616
Coefficient	Diesel oil	Fuel oil	Natural gas	Electricity	
γ_i	1.4571	1.4286	1.3300	0.1229	
	(kg sc/kg)	(kg sc/kg)	(kg sc/m ³)	(sc/kwh)	
δ_i (ton-coal/tsc)	0.657	0.717	0.523	1.814	

tsc means "ton of standard coal equivalent"; sc refers "standard coal".

There are forty-two sectors' data in Chinese Input-Output Table (2007). Due to less energy consumption and carbon emissions by the tertiary industry, all sectors within the tertiary industry are merged into only five sectors. In addition, several sectors in the secondary industry are also merged (see Table 3). Thus, we will deal with thirty sectors and for convenience they are numbered (see Table 4).

Table 3 Departments before and after merging

Industry	Departments before merging	Departments after merging
The Tertiary Industry	Services to household, education, health services and social welfare institutions culture, sports and entertainment services, and public utilities	Life consumption
	Wholesale, retail and restaurants	Wholesale, retail, and restaurants
	Financial institutions, real estate, rent services, research and scientific institutions, general technical services, water, environment and public facilities	Other services
	Transport and storage, communications, Information transmission, computer service and software	Transport, storage and communications
	Construction	Construction
The Secondary Industry	Telecommunication, special equipments	Telecommunication and special equipments
	Primary iron and steel manufacturing, Primary non-ferrous metals manufacturing	Iron and steel manufacturing

Table 3 continued

Manufacture of basic chemical and products, Manufacture of medicines, Manufacture of chemical fibers, Manufacture of rubber products, Manufacture of plastic products	Chemical industries
Manufacture of paper and paper products, printing industries, Manufacture of articles for culture, activities, education and sports	Manufacture of paper, printing industries, articles for culture, activities, education and sports
Sawmills and manufacture of furniture	Sawmills and manufacture of furniture
manufacture of textiles and manufacture of cloth, shoe and cat, leather fur and their products	manufacture of textiles
Manufacture of agricultural food, food manufacturing, manufacture of beverages, tobacco manufactures	food and tobacco manufacturing
Ferrous ore exploiting, non-Ferrous ore exploiting	ore exploiting

Table 4 Industries and corresponding sectors after merging

Sectors	Industries	Sectors	Industries
1	Agriculture, forestry, livestock, fishing, and water conversation	16	Telecommunication manufacturing
2	Coal exploiting/cleaning and screening	17	transport equipment manufacturing
3	Crude petroleum and natural gas production	18	electric machinery and instrument manufacturing
4	Ferrous ore exploiting	19	electronic and telecommunication equipment and the like
5	non-ferrous ore exploiting	20	Instruments, meters and culture equipment
6	Manufacture of agricultural food	21	Handicraft and other manufacturing industries
7	Textiles manufacturing	22	scrap and waste manufacturing
8	Garments, shoes and cats, leather fur and their products	23	Electricity, steam and hot water production and supply
9	Furniture manufacturing	24	Gas production and supply
10	paper and paper products manufacturing	25	Water production and supply
11	Petroleum refineries/coking/Nuclear processing	26	construction
12	basic chemical and products manufacturing	27	Transport, storage and communications
13	Non-metal minerals product	28	Wholesale, retail, accommodation and restaurants
14	Primary iron and steel manufacturing	29	Other industries
15	metal products manufacturing	30	Daily-life consumption

3 Calculation results and empirical analysis

3.1 Comparisons of carbon emission coefficients among industries

Based on the data of Input-Output Table and Energy Statistical Yearbook of China (2007), we obtain the thirty-sector's direct emission coefficients and total emission coefficients by using equations (1) and (2), as shown in Columns 2 and 4 of Table 5. It is found that TCEC is always

Table 5 Industries' carbon emission coefficients list

Sectors	DCEC.(ton/ten thousand Yuan)	Rank by DCEC.	TCEC.(ton/ten thousand Yuan)	Rank by TCEC	Percent change from DCEC to TCEC	Rank by percentage change
1	0.120567	18	0.379971	28	2.151541	18
2	0.531577	3	1.052404	7	0.979778	30
3	0.275766	11	0.675368	22	1.449058	23
4	0.248136	12	0.865085	14	2.486331	17
5	0.199269	13	0.767381	19	2.850974	16
6	0.083287	21	0.462981	26	4.558845	11
7	0.176146	15	0.792715	17	3.50033	13
8	0.041604	26	0.598791	25	13.39265	6
9	0.06352	23	0.62035	24	8.76617	9
10	0.185484	14	0.792225	18	3.271125	14
11	0.447042	6	1.068122	6	1.389313	24
12	0.379048	9	1.182254	3	2.119008	19
13	0.638198	2	1.377099	2	1.157792	26
14	0.68416	1	1.610211	1	1.35356	25
15	0.114383	19	1.088213	5	8.513723	10
16	0.072931	22	0.893066	13	11.24544	7
17	0.051534	24	0.807742	16	14.67391	5
18	0.040639	27	0.978945	9	23.08891	1
19	0.034839	29	0.672569	23	18.30514	3
20	0.037964	28	0.71416	21	17.81156	4
21	0.148637	16	0.822553	15	4.533956	12
22	0.008098	30	0.0894	30	10.0392	8
23	0.41953	7	1.135632	4	1.706911	21
24	0.397666	8	0.996719	8	1.506424	22
25	0.486277	4	0.9645	10	0.983437	29
26	0.045957	25	0.921767	11	19.0573	2
27	0.455122	5	0.906665	12	0.992135	28
28	0.097666	20	0.380474	27	2.895674	15
29	0.129084	17	0.377554	29	1.924869	20
30	0.366237	10	0.766541	20	1.09302	27

DCEC means "direct carbon emission coefficient"; TCEC refers "the total carbon emission coefficient".

greater than DCEC. The percent change from TCEC to DCEC is computed as in Column 6 of Table 5.

We can draw the following conclusions from Table 5.

(A) There is a big difference between DCEC and TCEC for some sectors. From Columns two and four, on the one hand, the 18th sector of electrical machinery and equipment manufacturing industry ranks fourth from the bottom (27th) in DCEC (0.040639) and the ninth from the top (9th) in TCEC (23.08891), with TCEC (23.08891) being 24 times DCEC (0.040639). Thus, there is a biggest percent change from DCEC to TCEC for the 18th sector and ranks No.1 in “the embodied carbon emission” among the thirty sectors^[18].

(B) There is big difference in the types of industries between ranks by DCEC and TCEC. One group is featured by evident and stable carbon emission, including the black metal smelting and rolling processing (14th sector) and the nonmetal mineral products industry (13th sector). These two sectors rank No.1 and No.2, respectively, and are recognized as “main carbon emitter” whether DCEC or TCEC is used to rank them. In addition, the oil processing and coking and nuclear fuel processing (11th sector), the black ore picking (4th sector) are also situated in the forefront of the sorting. However, the resource waste and recycled materials recovery processing (22th sector), the agricultural food processing (6th sector), the wood processing and wood, bamboo, cane, palm, grass industry (9th sector), and the textiles, garments, shoes, caps manufacturing (8th sector) with smaller DCEC and TCEC belong to typical relative low carbon industries.

(C) Seen from the fourth, sixth, and seventh column, these sectors are especially noteworthy for they are faced with a quite big difference between the direct coefficient and the complete coefficient, such as communications equipment, computer and other electronic equipment industry, wood processing and wood, bamboo, cane, palm, grassland manufacturing sector, and textiles, garments, shoes, caps manufacturing sector. Considering DCEC and TCEC together, their absolute coefficients rank in the last seven among the thirty departments. But the gap between DCEC and TCEC is the third, sixth and ninth respectively, which is explained by their numerous embodied carbon.

In conclusion, in order to implement energy conservation and emissions reduction, we should care about not only DCEC but also TCEC. We should keep a watchful eye on these sectors in the advanced position, such as black metal smelting and rolling processing, and those with absolute coefficients in the backward position but indirect emissions in the forefront, including communication equipment, computer and other electronic equipment industries. To strengthen the control of these industries is effective to achieve the purpose of energy conservation and emissions reduction.

3.2 The results and analysis of complete carbon emissions

Based on the economic data shown in Table 6, the calculation results are obtained (See Table 7).

From the Table 7 and the contribution proportion array (see Table 8) we learn the facts as follows.

Table 6 Economic data

Unit: ten thousand Yuan

Sectors	Final Consumption	Investment	Exports	Imports
1	114976729	20416358	6659785.1	23279609
2	1477904.7	322179.29	2337578.2	1921708.1
3	0.01	780969.97	1735647.8	57682693
4	0.01	1339651.6	822875.31	40779994
5	0.01	48479.645	1504403.3	3004363.7
6	166879064	9481045.3	19121135	15815255
7	4425356.6	1441898.8	82158911	8182909.9
8	56712197	1083606.5	56726409	6087705.9
9	5172106.4	12390713	24244658	2704832.5
10	4212454.8	870725.56	22644209	8286283.2
11	7459960.2	-584369.5	7678378.3	14501469
12	23510406	4922679	72379174	91051715
13	2796629.3	541400.82	14836921	3772993.1
14	0.01	6414101.4	51554905	43205060
15	4108598.7	10923437	35585167	5846909.6
16	648504.66	161909458	57368521	70433320
17	24564891	102519414	32821566	30032045
18	19230783	48783795	68256592	34351999
19	19378979	44527208	213775082	162987370
20	1797101.7	11395539	32373998	39298198
21	13827573	8817384.6	13097173	2218830.8
22	0.01	0.01	317293.34	14085868
23	23529606	0.01	651130.47	179856.87
24	3219925.1	52736.383	0.01	0.01
25	3221088	0.01	0.01	0.01
26	9318748.3	588465912	4088746.8	2212627.1
27	40319079	2892475.9	40315450	11038922
28	134956977	19848284	47440878	5233456
29	166652305	37247554	33217686	31633541
30	435232478	0.01	7230392.3	6386141.3

In 2007, the gross carbon dioxide emission generated from China's domestic final demand for consumption, investment and exports add up to 2.53 billion tons. Among them, the total carbon of construction business (No.26) is up to 0.555 billions tons, occupying the first place with a percentage of 21.96%. Therefore, to develop energy conservation building industry turns out to be one of the key direction towards energy saving and emission reduction. Besides, such industries as resource waste and recycled materials recovery processing (No.22), oil and

natural gas exploiting (No.3), and non-metal ore picking (No.5) rank the first, the second, and the third from bottom respectively. Meanwhile, the carbon emission produced from exports demand reaches 0.78 billion tons with a proportion of 31.1% of the annual emissions in total.

Table 7 The Industries' complete-carbon-emission list

Sectors	Unit: ton					
	Carbon consumption	Carbon investment	Carbon exports	Carbon imports	Net Carbon exports	Final demand
1	43687804	7757620.6	2530524.1	8845572.5	-6315048	53975949
2	1555353.3	339062.9	2460077.5	2022414.1	437663.45	4354494
3	0.0067537	527442.19	1172201.1	38957049	-37784848	1699643
4	0.0086508	1158912.2	711856.89	35278151	-34566294	1870769
5	0.0076738	37202.367	1154450.8	2305492.1	-1151041	1191653
6	77261802	4389541.9	8852718.5	7322159.2	1530559.3	90504062
7	3508045.7	1143014.5	65128584	6486713.8	58641871	69779644
8	33958727	648853.33	33967238	3645260.8	30321977	68574818
9	3208516.3	7686579.4	15040174	1677942.9	13362231	25935270
10	3337210.7	689810.28	17939302	6564598.1	11374704	21966323
11	7968150.1	-624178.1	8201447.3	15489343	-7287896	15545419
12	27795266	5819855.9	85570552	107646234	-22075682	1.19E+08
13	3851235.4	745562.52	20431909	5195785	15236124	25028707
14	0.0161021	10328059	83014296	69569280	13445016	93342355
15	4471028.7	11887021	38724226	6362680.4	32361545	55082276
16	579157.7	144595892	51233897	62901629	-11667733	1.96E+08
17	19842105	82809282	26511372	24258158	2253214.3	1.29E+08
18	18825870	47756629	66819417	33628702	33190715	1.33E+08
19	13033700	29947619	143778490	109620250	34158240	1.87E+08
20	1283419	8138242.8	23120228	28065218	-4944990	32541890
21	11373907	7252763.1	10773115	1825105.1	8948009.3	29399785
22	0.000894	0.000894	28366.06	1259278.2	-1230912	28366.06
23	26720962	0.0113563	739444.29	204251.13	535193.16	27460406
24	3209359.2	52563.333	0.0099672	0.0099672	0	3261923
25	3106739.6	0.009645	0.009645	0.009645	0	3106740
26	8589712.3	542428307	3768870.9	2039526.1	1729344.8	5.55E+08
27	36555893	2622506.3	36552603	10008603	26544000	75731002
28	51347604	7551753.5	18050015	1991193.3	16058822	76949373
29	62920163	14062945	12541454	11943354	598099.7	89524562
30	333623484	0.0076654	5542391.2	4895238.3	647152.89	3.39E+08
total	801615217	939752862	784359219	610009182	174350037	2.53E+09

Table 8 Contribution proportion array

Unit: percentage

Sectors	Carbon consumption	Carbon investment	Carbon exports	Carbon imports	Net Carbon exports	Final demand
1	0.054499719	0.008255	0.003226	0.014501	-0.03622	0.02137
2	0.001940274	0.000361	0.003136	0.003315	0.00251	0.001724
3	8.42511E-12	0.000561	0.001494	0.063863	-0.21672	0.000673
4	1.07917E-11	0.001233	0.000908	0.057832	-0.19826	0.000741
5	9.57292E-12	3.96E-05	0.001472	0.003779	-0.0066	0.000472
6	0.096382654	0.004671	0.011287	0.012003	0.008779	0.035833
7	0.004376221	0.001216	0.083034	0.010634	0.336346	0.027628
8	0.042362877	0.00069	0.043306	0.005976	0.173914	0.027151
9	0.004002564	0.008179	0.019175	0.002751	0.07664	0.010268
10	0.004163108	0.000734	0.022871	0.010761	0.065241	0.008697
11	0.009940118	-0.00066	0.010456	0.025392	-0.0418	0.006155
12	0.034674075	0.006193	0.109096	0.176467	-0.12662	0.047189
13	0.004804344	0.000793	0.026049	0.008518	0.087388	0.00991
14	2.00871E-11	0.01099	0.105837	0.114046	0.077115	0.036957
15	0.005577525	0.012649	0.049371	0.01043	0.185612	0.021808
16	0.000722488	0.153866	0.065319	0.103116	-0.06692	0.077763
17	0.024752655	0.088118	0.0338	0.039767	0.012924	0.051139
18	0.023484921	0.050818	0.08519	0.055128	0.190368	0.052817
19	0.016259297	0.031868	0.183307	0.179703	0.195918	0.073943
20	0.001601041	0.00866	0.029477	0.046008	-0.02836	0.012884
21	0.014188736	0.007718	0.013735	0.002992	0.051322	0.01164
22	1.11525E-12	9.51E-13	3.62E-05	0.002064	-0.00706	1.12E-05
23	0.033333901	1.21E-11	0.000943	0.000335	0.00307	0.010872
24	0.004003616	5.59E-05	1.27E-11	1.63E-11	0	0.001291
25	0.0038756	1.03E-11	1.23E-11	1.58E-11	0	0.00123
26	0.010715506	0.577203	0.004805	0.003343	0.009919	0.219654
27	0.045602793	0.002791	0.046602	0.016407	0.152245	0.029984
28	0.064055176	0.008036	0.023012	0.003264	0.092107	0.030466
29	0.078491727	0.014965	0.015989	0.019579	0.00343	0.035445
30	0.41618906	8.16E-12	0.007066	0.008025	0.003712	0.134284

In detail, the sectors including communications equipment, computer and other electronic equipment industry (No.19) are recognized as No.1 due to their highest ratio of 18.3%, equal to 0.144 billion tons. However, those that provide consuming products involving gas production and supply (No.24), water production and supply (No.25) follow in the rear.

Furthermore, the emission-reduction volume of imports is 0.61 billion tons with a percentage of 24.2%. And the industries of communication equipment, computer and other electronic equipment manufacturing (No.19), chemical raw materials and chemical products manufacturing (No.12) ranks the first and the second separately while both gas production and supply (No.24) and water production and supply (No.25) are the last and the last but one in the ranking.

As to net export carbon emission, it is up to 0.17 billion tons arising from global trade which makes China a carbon pollution inputting nation. The textiles industry achieved a biggest contribution ratio of 33.6%, which further emphasizes the face that China's exporting structure is still confined to a majority of industries with low value-added.

As far as consuming demand is mentioned, the carbon emission volume reaches 0.82 billion tons, of which consumer goods sector (No.30) with 0.33 billion tons accounting for 41.6% is far ahead of agricultural food processing sector situated in the second place with a percentage of 9.6% only. On the other hand, the resource waste and recycled materials recovery processing (No.22), oil and natural gas exploiting industry (No.3), and nonmetal ore picking (No.5) are in no doubt among the bottom three. Consider investment demand, the carbon emission produces 9.39 million tons of volume, where construction sector (No.26) ranks No.1 with the highest proportion of 57.7% equaling 5.42 billion tons, and oil processing and coking and nuclear fuel processing (No.11) are shown as negative values for they adopts inventory investment instead of zero investment demand, and the resource waste and recycled materials recovery processing (No.22) sector should bring up the rear.

As for the above empirical results, we make some analysis of each industry in question from their actual development status.

The construction industry in China takes up 10% of the newly increased building output annually in the world. A majority of the buildings are dependent on high volume of carbon and energy consumption resulting from such bottlenecks as mass production, inferior quality, short life, unnecessarily big house type, old-fashioned design, and less strategic support from governments. The most influential determinant lies in the fact that some buildings at home only live 50-to-60 year or even 10-to-20 year prior to demolition or reconstruction, falling far behind developed countries who have witnessed their building ranging from 100 to 150 years^[19]. Additionally, the construction industry has made excessive use of high-emission cement as one of raw materials. And as to the cement manufacturing sector, approximately two thirds of cement output stem from limestone's chemical decomposition, which is exemplified by the 1.06-billion-ton cement accompanied by 0.39 billion tons of CO₂ in 2005 and 1.65-billion-ton cement with CO₂ emission of 0.56 billion tons in 2009^[20]. All in all, it is well advised to pay great attention to the construction industry that generates the largest amount of carbon emission among all the industries and sectors in China.

Communication equipment, computer and other electronic equipment industry, in accordance with carbon emissions coefficients mentioned above, is perceived as a foreign-trade-oriented sector featured by most significant carbon intensity, which is closely connected with its internal attributes of high-tech and high-energy-consumption. In other words, it has consumed enormous energy with constant expansion of internet scale and growth of telecommunications

webs that are triggered by increasingly-developed network, power system and computer room, base-station, etc. Up to now, China has possessed almost a thousand lord exchange equipment sets and several-hundred thousand base stations that constitute an uninterrupted network environment, which actually requires a considerable amount of energy. For instance, the base stations annually consume power reaching to 7 billion degree on average by using air conditioners. And the total sum of electricity consumption in 2009 is more than 20 billion degree for the telecommunications industry as a whole^[21].

Concerning daily living consumption sectors, with the rapid and sustainable growth of our economy, the living standards of urban and rural residents has improved a lot and the energy consumed in daily life have soared remarkably, especially during the recent 20 years the total living consumption has risen from 9583 thousand tons in 1980 to 26789.7 thousand tons in 2007 with an annual average growth rate of 3.74%^[22]. It is the household electronic appliances and cars that lead to higher energy consumption and more carbon emission. For example, average car ownership for a urban family has increased from 0.34 units per one-hundred family in 1999 to 6.06 units in 2007, while for rural residents, average ownership of refrigerators per one-hundred family has reached from 1.22 sets in 1990 to 26.12 sets in 2007^[23]. Furthermore, considering rural residents rigid demand for energy and the approaching stage of well-off society, Chinese residents and those living in rural areas in particular are sure to suffer from higher pressure related to living energy and carbon emission.

4 Conclusion and suggestions

This article makes use of the latest input-output data of 2007 to obtain the results of complete carbon emissions of different industries that partial industries belong to obvious high-carbon industry, whether from the direct coefficient or complete coefficient, such as black metal smelting and rolling processing, nonmetal mineral products industry; some belong to high-carbon intensity industry, such as electrical machinery and equipment manufacturing construction, and the direct coefficient is bigger than the complete coefficient; other sectors are especially noteworthy which is big different between the direct coefficient and the complete coefficient, such as communications equipment, computer and other electronic equipment industry. From the perspective of total amounts, construction is the first industry to satisfy domestic demand, and communication equipment, computer and other electronic equipment industry is the most significant of trade departments.

We attempt to raise some useful suggestions with respect to energy conservation and emission reduction as follows.

1) Promoting innovation of technical standard system in order to guide industries in energy saving. As for the construction industry, it is strongly recommended to draw up a housing industrialization technical system and to tailor industrialization measure including “building blocks” type housing, which is surely to reduce energy consumption arising during building construction and at the same time to cut down building rubble and thus protect the environment effectively. We are also required to implement mandatory new-energy-application policy with the purpose of improving awareness of benefits from energy reduction projects. Besides, it is an effective approach to solve shortage of talents needed in this brand new area by cooperating

with colleges and universities and with social certificate training organization related. Furthermore, it is necessary to formulate technical criteria for products and/or services involved in telecommunications industry, accompanied by such means as monitoring goods energy-saving index and controlling energy consumption generated by telecommunications equipments and generator rooms in particular. Finally, it is needed to work out a guideline of cleaner production for staffs in relevant industries and certain special projects plans on key energy-saving technologies promotion.

2) Pushing innovation of energy-saving-oriented economic management in order to idealize the strategic carbon-emission-reduction system covering finance, revenue, banking and price-setting. To start with, financial strategies are required to target low-carbon techniques and call for more investment in this area by establishing stated-owned engineering centers and laboratories specializing in energy saving, resources utilization and environment protection. In addition, experts and technicians should be encouraged to tackle key problems of high efficient generation of power, cleaner production in seriously-polluted industries, and emission reduction in the field of construction industry, and to develop a series of technologies that are able to be applied universally in almost every industry or sector. Then as for banking and revenue strategies, they should pay more attention to energy-saving-oriented manufacturers together with relevant projects by encouraging banks to provide them with financial aid. The advisable specific measures include allowing them to apply for mortgage loan that will be invested in energy conservation projects, agreeing to reduce or even cancel taxes on energy-management contracts, stimulating energy management companies to set foot in public infrastructure such as municipal lighting and large-scale public property, etc., and further boosting price reforms in terms of resource products, oil tax, natural gas, industrial electricity, residents electricity, water and so on.

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