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Original Research

An Electric Carbon Productivity Analysis of China's Industrial Sector Using Multi-Dimensional Decomposition

Wei Sun[1]*, Yujun He[2], Huisheng Gao[2]

[1]Department of Economics and Management, North China Electric Power University, Baoding, Hebei 071003, China
[2]School of Electrical and Electronic Engineering, North China Electric Power University, Baoding, Hebei 071003, China

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Abstract

Carbon productivity is a special indicator that coordinates economic development and climate resource protection. Similar to carbon productivity, electricity carbon productivity (ECP) is defined and researched in our paper since it is an effective way for China's power industry to realize the low-carbon development path. In this work we have applied the multi-dimensional decomposition method to ECP time series decomposition in order to explore the contributions of technological improvement and structure adjustment for each industrial sector from the final electricity aspect. Moreover, the time-dependent changes of ECP for the period of 2000-14 are researched considering the effects of accumulated technological improvement and structure adjustment. According to the decomposition results, a roadmap for raising carbon productivity by reducing emissions with a minimal impact on electricity demand is provided.

Keywords: low carbon electricity, electric carbon productivity, multi-dimensional decomposition

Introduction

Since the industrial revolution, the fact that greenhouse gas (GHG) emissions from human activities will lead to global climate change has been tested by the Intergovernmental Panel on Climate Change (IPCC) and other organizations [1-3]. The most direct and fundamental reason to put forward a low-carbon economy is to cope with climate change. Carbon productivity is an important indicator to coordinate economic development and climate resource protection, as shown in the Climate Change Special Initiative Report by Mckinsey and Company in 2008 [4]. Carbon productivity, as proposed by Kaya andYokobori (1999) [5], is originally defined as the amount of GDP produced per unit of carbon emissions [6-7]. Improving carbon productivity is the essential way to coordinate economic development and climate protection, which is recognized by the Energy Information Administration (EIA), the World Bank, and the IPCC.

China, the largest CO_2 emitter, is facing ever-increasing pressure on reducing emissions. The core of dealing with climate change is to reduce fossil fuel consumption for electricity generation, heat supply, and transport, which is the main source of CO_2 emissions. In China, thermal power plants consumed more than half of

*e-mail: hdprettyweiwei@126.com

the national total coal consumption [8]. Due to the high proportion of fossil fuels, the electric power industry is a major contributor to national CO_2 emissions – with 40% of total emissions. Whether the GHG emissions reduction target of China can be successfully achieved depends largely on emissions growth from the power industry being effectively controlled.

The measure of carbon productivity helps to reveal the level of low carbon economy for a country and the corresponding development stage of it [9]. Carbon productivity has been used to evaluate the effects on productivity of environmental tax reform [6], to assess the environmental quality of multi-industry development [10], and to investigate the efficiency of the carbon emissions of industries so as to establish a corresponding relationship between carbon emissions and economy of scale of industries [7]. He [11] estimated China's rate of carbon productivity growth to coordinate economic development with emissions control, and finally suggested a sustainable development strategy in considering climate change issues. Liu [12] has proposed that China decouple development between eco-social welfare and carbon dioxide emissions by dividing carbon productivity to special carbon productivity based on economic performance and general carbon productivity based on welfare performance.

Pen [13] estimated the carbon productivity of 29 provinces in China during 1995-2010 and analyzed the convergence of carbon productivity in eastern, central, and western regions. Meng [14] presented an absolute and relative decomposition model for the change in carbon productivity and revealed some important policies. Pan [15] calculated regional carbon productivity, analyzed the regional difference using clustering technique and the Theil and decoupling indices, and finally put forward countermeasures of carbon reduction targets. No study so far has focused on the research of carbon productivity in the electric power industry. Wang [9] applied the global Luenberger carbon productivity indicator to evaluate the carbon productivity change in different energy-driven CO_2 emissions of 37 major emitting countries and regions in 1995-2009. Long [16] measured the industrial carbon productivity of 30 provinces in China from 2005 to 2012 and examined the space-time characteristics and the main factors of China's industrial carbon productivity using Moran's I index and spatial panel data models. Hu [17] applied the log mean divisia index decomposition method to explore the factors influencing carbon productivity change of the Australian construction industry from 1990 to 2012. Zhao [18] evaluated the generalized carbon-productivity index from 2004-09 of the Chinese industrial sector based on directional distance function and data envelopment analysis method. Lu [19] performed a quantitative decomposition of carbon productivity by using an LMDI decomposition model at provincial level.

According to [20], carbon productivity can be thought of in a similar way as labour productivity or capital productivity. In our work, the electric carbon productivity can be defined similarly. Just like carbon productivity, electric carbon productivity (ECP) is the amount of economic output produced due to the electricity consumption per ton of carbon emitted. Researching ECP and its characteristics is an effective way to improve our carbon productivity with important research value and practical significance.

Among the most popular decomposition models, including the logarithmic mean divisia index (LMDI) and Laspeyres, we selected LMDI as the basic algorithm in our work to treat the ration indicator-ECP. And the change of ECP indicator is decomposed from multi-dimensions, including time, the industrial sector, and electricity consumption efficiency. The decomposition results can provide suggestive low carbon development policies for different industrial sectors.

Theory of Electric Carbon Productivity and Decomposition Technique

Concept of Electric Carbon Productivity

Carbon productivity as defined by Kaya and Yokobori (1999) [5] is the amount of economic output produced per unit of carbon emissions. Electric carbon productivity (ECP) is defined as the ratio of economic output resulting from electricity consumption to the amount of CO_2 emitted:

$$P = G/D \tag{1}$$

…where P is electric carbon productivity, G is economic output, and D represents CO_2 emissions for the corresponding economic output.

Multi-Dimensional Decomposition Method

According to the ECP concept and considering the carbon emissions from different industrial sectors, the ECP for a country is shown by Eq. (2):

$$P = G/D = \sum_{i=1}^{n} \frac{G_i}{D_i} \cdot \frac{D_i}{D} \tag{2}$$

… where G_i is economic output by industrial sector i (here i = 1, 2, 3, 4, 5, 6 represents primary industry, industry, construction, transport (storage and post), wholesale (retail, hotel, restaurants), and other service industries) and D_i is the CO_2 emissions for the corresponding sector i. Due to the absence of power structure data for electric power consumption for the end-use sectors in the present statistical yearbook, the total CO_2 emissions for all sectors' electricity consumption is replaced by the CO_2 emissions generated by thermal power plants in the power supply side. And the CO_2 emissions for one certain sector are proportional to the amount of its electricity consumption.

For example:

$$D_i = D \times \frac{E_i}{E} \tag{3}$$

… where E_i is the electricity consumption for sector *i* and *E* is total electricity consumption for all industrial sectors.

With the development of energy efficiency, technology improvement, and economic adjustment, the value of ECP changes over time. We take the differentiation of Eq. (1) with respect to time [14, 19]:

$$\frac{dP}{dt} = \underbrace{\sum_{i=1}^{n} \frac{D_{it}}{D_t} \frac{d\left(\frac{G_{it}}{D_{it}}\right)}{dt}}_{(a)} + \underbrace{\sum_{i=1}^{n} \frac{G_{it}}{D_{it}} \frac{d\left(\frac{D_{it}}{D_t}\right)}{dt}}_{(b)} \tag{4}$$

… where (a) represents the ECP variation resulting from the change of energy efficiency and technology improvement for sector *i* and (b) reveals the ECP variation due to the change in emissions for sector *i*, which originates from the adjustment in economic structure. The change of ECP from time point *a* to time point *b* can be realized through definite integral operation, as shown in Eq. (5):

$$P_b - P_a = \sum_{i=1}^{n} \int_a^b \frac{D_{it}}{D_t} \frac{d\left(\frac{G_{it}}{D_{it}}\right)}{dt} + \sum_{i=1}^{n} \int_a^b \frac{G_{it}}{D_{it}} \frac{d\left(\frac{D_{it}}{D_t}\right)}{dt} \tag{5}$$

Next, the LMDI method is selected as the mean algorithm to treat the time-dependant variables $\frac{D_{it}}{D_t}$ and $\frac{G_{it}}{D_{it}}$ according to Ref. [14, 21, 22]. Eq (5) can be transformed into:

$$P_b - P_a = \sum_{i=1}^{n} \eta_{i(a,b)} \cdot \left(\frac{G_{ib}}{D_{ib}} - \frac{G_{ia}}{D_{ia}}\right) + \delta_{i(a,b)} \cdot \left(\frac{D_{ib}}{D_b} - \frac{D_{ia}}{D_a}\right) \tag{6}$$

…where $\frac{D_{it}}{D_t}$ is replaced by $\eta_{i(a,b)} = \frac{L\left(\frac{G_{ia}}{D_a}, \frac{G_{ib}}{D_b}\right)}{L\left(\frac{G_{ia}}{D_{ia}}, \frac{G_{ib}}{D_{ib}}\right)}$; and $\frac{G_{it}}{D_{it}}$ is replaced by $\delta_{i(a,b)} = \frac{L\left(\frac{G_{ia}}{D_a}, \frac{G_{ib}}{D_b}\right)}{L\left(\frac{D_{ia}}{D_a}, \frac{D_{ib}}{D_b}\right)}$. We define $L(x,y) = \begin{cases} (x-y)/(\ln x - \ln y), & x \neq y \\ x, & x = y \end{cases}$.

Table 1. The GDP value for each industrial sector (Unit: 100 million Yuan).

	GDPT	GDPP	GDPI	GDPC	GDPR	GDPW	GDPS
2000	99,214.55	14,944.72	40,033.59	5,522.29	6,160.95	10,304.85	22,248.15
2001	109,655.17	15,781.27	43,580.62	5,931.67	6,870.25	11,519.54	25,971.82
2002	120,332.69	16,537.02	47,431.31	6,465.46	7,492.95	12,720.10	29,685.85
2003	135,822.76	17,381.72	54,945.53	7,490.78	7,913.19	14,295.53	33,796.01
2004	159,878.34	21,412.73	65,210.03	8,694.28	9,304.39	16,118.65	39,138.30
2005	184,937.37	22,420.00	77,230.78	10,367.31	10,666.16	18,161.89	46,091.22
2006	216,314.43	24,040.00	91,310.94	12,408.61	12,182.98	21,323.31	55,048.59
2007	265,810.31	28,627.00	110,534.88	15,296.48	14,601.04	26,485.95	70,264.96
2008	314,045.43	33,702.00	130,260.24	18,743.20	16,362.50	32,798.41	82,179.07
2009	340,902.81	35,226.00	135,239.95	22,398.83	16,727.11	36,102.63	95,208.29
2010	401,512.80	40,533.60	160,722.23	26,660.98	19,132.19	43,814.55	110,649.25
2011	473,104.05	47,486.21	188,470.15	31,942.66	22,432.84	52,618.05	130,154.13
2012	519,470.10	52,373.63	199,670.66	35,491.34	24,660.00	59,858.62	147,415.86
2013	568,845.21	56,957.00	210,689.42	38,995.00	27,282.93	67,165.90	167,755.00
2014	636,139.00	61,072.41	217,805.43	41,748.99	30,633.98	75,056.23	209,821.93

Note: GDPT is total GDP for all industrial sectors; GDPP is GDP of primary industry; GDPI is GDP of industry; GDPC is GDP of construction; GDPR is GDP of transport, storage, and post industries; GDPW is GDP of wholesale, retail, hotel, and restaurants; and GDPS is GDP of other service industries.

Table 2. CO_2 emissions for each industrial sector (unit: 100 million tons).

	ECT	ECP	ECI	ECC	ECR	ECW	ECS
2000	12.03	0.55	9.96	0.16	0.29	0.43	0.64
2001	12.87	0.59	10.67	0.15	0.31	0.45	0.70
2002	14.40	0.61	12.02	0.17	0.34	0.50	0.76
2003	16.71	0.69	13.90	0.19	0.40	0.62	0.91
2004	19.21	0.76	16.04	0.22	0.44	0.73	1.02
2005	21.47	0.76	18.03	0.23	0.42	0.73	1.31
2006	24.37	0.80	20.53	0.26	0.45	0.82	1.50
2007	26.83	0.82	22.75	0.29	0.50	0.87	1.60
2008	27.36	0.81	23.04	0.33	0.52	0.92	1.74
2009	28.77	0.84	24.02	0.38	0.55	1.02	1.96
2010	32.25	0.86	27.05	0.42	0.64	1.13	2.15
2011	35.82	0.88	30.03	0.49	0.73	1.30	2.38
2012	37.34	0.87	31.07	0.52	0.79	1.45	2.64
2013	39.99	0.88	33.15	0.58	0.86	1.61	2.91
2014	42.62	0.96	35.34	0.61	0.88	1.71	3.12

Note: ECT is total carbon emissions for all industrial sectors; ECP is carbon emitted in primary industry; ECI is carbon emitted in industry; ECC is carbon emitted in construction; ECR is carbon emitted in transport, storage, and post industries; ECW is carbon emitted in wholesale, retail, hotel, and restaurants; and ECS is carbon emitted in other service industries.

Table 3. ECP for each industrial sector (unit: 10^4 Yuan/ton CO_2).

	ECPT	PECP	IECP	CECP	RECP	WECP	SECP
2000	0.8247	2.7172	0.4019	3.4514	2.1245	2.3965	3.4763
2001	0.853	2.6644	0.4126	3.8453	2.2121	2.5739	3.6893
2002	0.8325	2.6873	0.3979	3.5537	2.2306	2.5554	3.8509
2003	0.8002	2.4947	0.388	3.452	2.0495	2.2938	3.6918
2004	0.8084	2.6878	0.3929	3.2802	2.0779	2.2279	3.8458
2005	0.8204	2.7393	0.4073	3.5436	2.437	2.4323	3.4922
2006	0.8193	2.7213	0.4113	3.5127	2.565	2.3581	3.5624
2007	0.8738	3.1219	0.4294	3.5714	2.6875	2.563	4.0672
2008	1.0073	3.6148	0.4992	3.6987	2.9309	2.8655	4.4531
2009	1.0435	3.5804	0.5022	3.7325	2.9524	2.8119	4.6136
2010	1.0848	3.9507	0.5191	3.7902	2.8703	2.9649	5.0082
2011	1.1482	4.4408	0.5453	3.7266	2.9157	3.0347	5.4392
2012	1.2308	4.8546	0.5692	3.8293	3.0117	3.0818	5.7615
2013	1.4225	6.4724	0.6356	6.7233	3.1724	4.1718	5.7648
2014	1.4926	6.3617	0.6163	6.8441	3.4811	4.3893	6.7251

Note: ECPT is total electric carbon productivity for all industrial sectors; PECP is electric carbon productivity for primary industry; IECP is electric carbon productivity for industry; CECP is electric carbon productivity for construction; RECP is electric carbon productivity for transport, storage, and post industries; WECP is electric carbon productivity for wholesale, retail, hotel, and restaurants; and SECP is electric carbon productivity for other service industries.

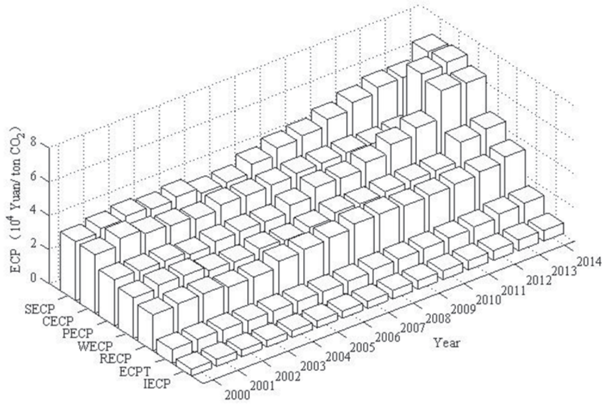

Fig. 1. ECP trends in China from 2000 to 2014.
Note: ECPT is total electricity carbon productivity; PECP is electricity carbon productivity for primary industry; IECP is electricity carbon productivity for industry; CECP is electricity carbon productivity for construction; RECP is electricity carbon productivity for transport, storage, and post industry; WECP is electricity carbon productivity for wholesale, retail, hotel, and restaurants; and SECP is electricity carbon productivity for other service industries.

Data Source

In this study, the GDP data for industrial sectors measured in 100 Million Yuan in constant 2000 price in China are collected from various issues of the *Chinese Statistical Yearbook* (CSY) [23]. The total CO_2 emissions from final electricity consumption can be calculated by multiplying power consumption with the corresponding CO_2 emission coefficient per unit of kilowatt hours. The data on power consumption are obtained from various issues of the Chinese Electric Power Yearbook [24]. The CO_2 emission coefficient per unit of kilowatt hours is offered by the International Energy Agency (IEA) in CO_2 emissions from fuel combustion highlights report [25]. CO_2 emissions from certain industrial sectors are in proportion to the amount of electricity consumption. Through Eq. (3), the emissions for each industrial sector can be calculated. The original data on GDP and CO_2 emissions for each industrial sector from 2000 to 2014 are shown in Table 1 and Table 2. According to Eq. (2), the ECP for the whole country and all the industrial sectors can be calculated, which are shown in Table 3.

Fig. 1 shows the main trends of ECP for different industrial sectors and the total ECP trend in China, which shows a gradual rising feature seen from Fig. 1 Through Eq. (4), we can defer that the increasing trend of ECP results from technology improvement and the different ECPs in different industrial sectors demonstrate that the industrial structure adjustment may result in changes to sector ECP. From Table 3 we can see that the total ECP increases from 0.8247(10^4 Yuan/ton CO_2) in 2000 to 1.4926 (10^4 Yuan/ton CO_2) in 2014; and the sector ECP for industry, construction, transport, wholesale, and services increases, respectively, from 2.7172, 0.4019, 3.4514, 2.1245, 2.3965, and 3.4763 in 2000 to 6.3617, 0.6163, 6.8441, 3.4811, 4.3893, and 6.7251 in 2014. In all, the improvement in ECP may be a combination of technological innovation and structure adjustment. However, the change amplitude is different for all sectors. The main reasons depend on decomposition and how the corresponding developing suggestion can be concluded.

Decomposition Results and Analysis

Using the GDP and CO_2 emissions data for all industrial sectors shown in Tables 1 and 2, the parameters $\eta_{i(a,b)}$ and $\delta_{i(a,b)}$ in Eq. (6) can be calculated based on

Table 4. Decomposition results of technological improvement for industrial sectors.

	00-01	01-02	02-03	03-04	04-05	05-06	06-07
Primary industry	-24.19	10.11	-80.59	78.04	19.29	-6.15	126.80
Industry	88.07	-122.30	-82.55	41.36	120.52	33.67	152.68
Construction	49.02	-34.21	-11.79	-19.60	29.16	-3.31	6.30
Transport, storage, and post	21.13	4.40	-43.04	6.64	75.95	24.31	22.72
Wholesale, retail, hotel and restaurants	62.72	-6.46	-93.85	-24.75	73.45	-25.10	67.67
Other services	114.62	86.57	-85.30	82.81	-201.20	43.05	305.74
	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Primary industry	148.22	-10.12	103.30	125.37	98.97	365.88	-24.64
Industry	589.79	24.90	141.40	219.97	200.08	550.77	-159.59
Construction	14.55	4.28	7.56	-8.48	14.17	41.21	17.41
Transport, storage, and post	45.83	4.10	-15.99	9.12	19.93	34.30	65.03
Wholesale, retail, hotel, and restaurants	99.94	-18.52	53.95	24.90	17.65	431.41	87.40
Other services	237.80	105.69	265.87	286.82	221.04	2.34	700.93

Table 5. Decomposition results of structure adjustment for industrial sectors.

	00-01	01-02	02-03	03-04	04-05	05-06	06-07
Primary industry	3.34	-93.17	-27.68	-44.79	-112.98	-70.20	-66.00
Industry	4.60	22.94	-11.34	12.28	19.18	10.86	23.13
Construction	-59.89	5.57	-15.24	2.76	-25.22	-1.54	4.96
Transport, storage, and post	-0.42	-10.57	6.99	-21.32	-75.14	-27.42	4.48
Wholesale, retail, hotel, and restaurants	-19.35	-6.23	57.65	20.29	-93.07	-8.45	-30.03
Other services	42.62	-60.77	63.37	-51.28	289.96	18.90	-72.97
	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Primary industry	-32.18	-14.68	-95.14	-87.91	-58.86	-72.68	33.31
Industry	-27.00	-36.09	19.72	-2.13	-34.96	-18.81	1.45
Construction	45.54	42.61	-6.96	24.66	9.32	29.75	-12.96
Transport, storage, and post	10.39	3.27	21.19	15.47	23.04	10.77	-28.51
Wholesale, retail, hotel, and restaurants	32.53	51.88	-11.98	37.61	77.68	51.43	-5.91
Other services	168.74	205.38	-70.18	-11.66	238.49	119.10	27.23

Table 6. Decomposition contribution results.

	00-01	01-02	02-03	03-04	04-05	05-06	06-07
Technological improvement	311.35	-61.90	-397.11	164.50	117.17	66.48	681.92
Structure adjustment	-29.10	-142.22	73.75	-82.07	2.74	-77.86	-136.44
Total contribution	282.25	-204.12	-323.36	82.43	119.91	-11.38	545.48
	07-08	08-09	09-10	10-11	11-12	12-13	13-14
Technological improvement	1136.12	110.32	556.09	657.70	571.85	1425.91	686.54
Structure adjustment	198.03	252.38	-143.35	-23.96	254.69	119.56	14.61
Total contribution	1334.15	362.70	412.74	633.74	826.54	1545.47	701.15

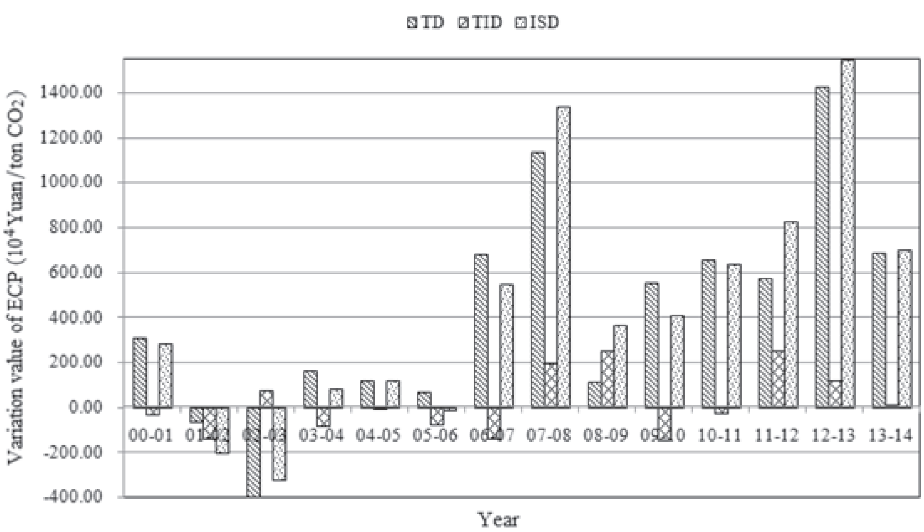

Fig. 2. Decomposition contribution of technological improvement and structure adjustment for ECP.

Note: TD is total decomposition contribution, TID is technological improvement decomposition contribution, and ISD is industrial structure adjustment decomposition contribution.

Table 7. Accumulated decomposition results of each industrial sector.

	Technological improvement	Structure adjustment	Total influence
Primary industry	930.29	-739.63	190.66
Industry	1,798.77	-16.18	1,782.59
Construction	106.28	43.35	162.57
Transport, storage, and post	274.42	-67.78	206.64
Wholesale, retail, hotel, and restaurants	750.41	154.06	904.46
Other services	2,166.78	906.92	3,073.70

Eqs. (4-6). The decomposition results for technological improvement and structure adjustment, which are the first and second part in Eq. (4), can be obtained. The total variation of China's ECP is decomposed into the effect of technological improvement and structure adjustment. Table 4 reflects the decomposition contributions of technological improvement of each industrial sector for the period 2000-14, and Table 5 shows the decomposition contributions of structure adjustment in the same period.

Total contributions of technological improvement from 2000 to 2014 can be obtained by summarizing the results of technological improvement of Table 4 by column. Similarly, the total contribution of structure adjustment for the same period can be determined by summarizing the results in Table 5 by column. Finally, total decomposition contribution, technological improvement decomposition contribution, and industrial structure adjustment decomposition contribution are shown in Table 6, which are also plotted in Fig. 2.

For times series change of ECP (Table 6), 2001-03 is the main period in which ECP decreased. The possible reasons for the decrease from 2001 to 2002 are the technological improvement of industry, construction, wholesale, retail, hotel, and restaurants, and the structure adjustment of all sectors except industry and construction. The main reasons for the decrease from 2002 to 2003 are technological improvement of all sectors and structure adjustment of primary, industry, and construction. The main reasons for the changes are explained as follows.

After the Southeast financial storm, the increasing export demand resulted in the growth of output production. More and more low-efficiency electrical enterprises with large high-efficiency electricity enterprises were put into production, especially during 2001-04, which results in a decrease in ECP for all industrial sectors. Our goal for industry is to introduce high-electricity efficiency equipment to improve ECP.

The structure adjustments in primary, industry, and construction were not satisfied during 2002-03, which is due to the economic recovery and the increasing demand for energy, materials, and buildings. China is still in the process of modernization and urbanization so that more energy and electricity are needed due to industrial production and increases in urban populations. Therefore, adjusting industry and construction is a difficult task in the future.

The quantitative influence of techonological improvement for each industrial sector can be obtained

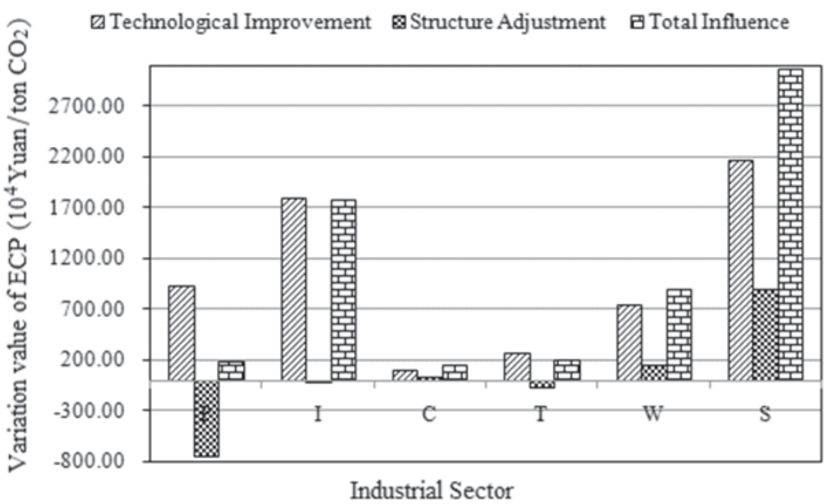

Fig. 3. Accumulated decomposition results of each industrial sector for 2000-12.
Note: P is primary industry; I is industry; C is construction; T is transport, storage, and post; W is wholesale, retail, hotel, and restaurants; and S is other services.

by summarizing the values of Table 4 by rows. Similarly, the sum of elements in the rows of Table 5 is the quantitative influence of structure adjustment. The total influence for each industrial sector is the combination of technological improvement and strucure adjustment. The resutls of technological improvement, structure adjustment, and total influence are shown in Table 7 and the quantitative influences are plotted in Fig. 3.

Overall, all the industrial sectors have made certain improvements in technology and structure adjustment except for primary industry. The first two largest contributors are the services sector (3,073.70) and industry (1,782.59), followed by wholesale (904.46), transport (206.64), construction (162.57), and primary industry (190.66). For industry, the contribution of structure adjustment is limited, which can almost not be seen in Fig. 3. During the research period, the proportion of the second industry is maintained at a relatively stable level of about 45%. The main reason is that China is in the rapid process of industrialization, and a number of carbon-intensive industries are still the backbone to support the development of the national economy. China's industrial sector will focus on in-depth structure adjustment and development mode transformation during the period of the 12th Five-Year Plan. China's economic shift away from heavy industry toward high value-added industry will lead to reasonable industrial structures and increase industrial ECP. It is clear that the technology improvement in the industry sector has an obvious effect on total ECP improvement, which indicates that the electrical equipment efficiency is obviously increased due to the elimination of inefficient energy equipment. For the service industry, there are manifest improvements in technology and structure adjustment. But for primary industry the total influence on changes of ECP shows a negative effect. One possible reason is that the output reduction in primary is greater than its corresponding emissions. So the ECP for primary industry has declined.

Suggestive policies for industrial sector development can be provided from quantitative decomposition analysis. First, improve the electricity efficiency in industry. The production situations of electricity-intensive industries, such as the metallurgical, non-ferrous metals, chemical, and building materials industries are more serious. There are many small-scale low-efficiency plants. One key task for the Chinese government is to close these small plants and encourage higher-efficiency enterprises. Second, deepen industrial structure adjustment. The Chinese government needs to further adjust industrial structure, which means shifting away from electricity-intensive and low-added industrial sub-sectors to electricity-efficient and high-added sectors, thereby improving electricity efficiency in industries. The scientific and sustained industrial structure will lead to smaller electricity intensity. The 13th Five-Year Plan is expected to contain preferential measures for developing electricity-efficient technologies so as to maintain continuous improvement in electricity carbon productivity. Third, develop an electricity-saving service industry. The special electricity-saving service company provides electricity-saving diagnosis and reformation to improve electrical efficiency. The electricity-saving service company has already coordinated with many fields such as industry, construction, transport, and so on. It is also the long-term energy development strategy in the future.

Conclusions

Understanding how to enhance electricity carbon productivity (ECP) is vital for China's power industry to address climate change. In this paper, a multi-dimensional decomposition is designed for ECP time series decomposition from the aspect of end electricity use. Using the decomposition mode, the ECP can be decomposed into technological improvement effect and structure adjustment effect. The quantitative effects of technological improvement and structure adjustment on industrial sectors are explored. And the accumulated contribution of technological improvement and structure adjustment to total ECP is also studied. Finally, the suggestive low carbon development policies based on improving ECP for different industrial sectors are provided.

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