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Xueting Zhao
xueting.zhao@mail.wvu.edu

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Estimation of China Sectoral Emission Intensity: Based on Input-Output Model

Xueting Zhao

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Estimation of China Sectoral Emission Intensity: Based on Input-Output Model

Abstract

With strong economic growth, China's energy consumption and CO₂ emissions grow quickly. The energy shortage and environmental problem have become the bottleneck of further economic growth. The most popular method to estimate the environmental impact is the Environmental input-output analysis, and the most important data support is the sectoral emission intensities. This Resource Document describes the process to estimate the China sectoral CO₂ emission intensities based on the Disaggregated Input-Output table (suggest to read the Technical Document: Disaggregating Input-Output Models). This document includes the data sources, calculation process and the procedural notes. The calculation includes both the national China and Shanxi province.

1 Data Sources

The data in this document are from several sources, including Statistical Yearbooks, Input-Output tables, IPCC Guideline, and the journal paper.

1.1 Input-Output Tables

- 2007 China Input-Output Table (42 sectors)
- 2007 Shanxi Input-Output Table (42 sectors)

These Input-Output tables are disaggregated into the 50 by 50 sectors tables (suggest to read the Technical Document: Disaggregating Input-Output Models).

1.2 Statistical Yearbooks

- China Energy Statistical Yearbook 2008
 - Energy consumption and its composition by sector

* The energy consumption data includes eight fuel types: coal, coke, gasoline, diesel, crude oil, kerosene, fuel oil and natural gas.

- Conversion factors (KJ/Kg,m³)

* The conversion factors are the calorific value of each fuel type in China.

- Shanxi Statistical Yearbook 2008

- Energy consumption and its composition by sector

* The energy consumption data includes four fuel types: coal, coke, gasoline, and diesel.

1.3 IPCC Guideline

- CO₂ emission factor by fuel type (default value, kgCO₂/TJ)

2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Energy, Chapter 1, Introduction, Page 23, Table 1.4, provides the effective CO₂ emission factor of each different fuel type.

The CO₂ emission factors and the conversion factors that used in this document are summarized as below.

Fuel Type	IPCC CO ₂ Emission Factor	Conversion Factor (Calorific Value)
	(kgCO ₂ /TJ)	(KJ/Kg,m ³)
Coal	94600	20908
Coke	107000	28435
Gasoline	70000	43070
Diesel	74100	42652
Crude Oil	73300	41816
Kerosene	71900	43070
Fuel Oil	71500	41816
Natural Gas	56100	38931

Figure 1: CO₂ emission factors and the conversion factors

1.4 Journal Paper

The Input-Output tables that used in this document are the disaggregated 50 by 50 sectors tables. The CO₂ emissions of the new sectors are calculated according to the data in the Lindner's paper (2013).

Technology	CO ₂ intensity of power plant (gCO ₂ /kwh)	Power Generation in percentile fractions	
		National Average	North China (Shanxi)
Hydroelectricity	18	0.22	0.03
Coal sub-c	1000	0.64	0.83
Coal super-c	900	0.06	0.08
Coal USC	750	0.03	0.01
Natural gas	400	0.01	0
Nuclear	45	0.01	0.01
Wind	10	0.02	0.04
Solar - PV	30	0.01	0

Figure 2: CO₂ intensity and power generation of different power plants

2 Calculation Process and Procedural Notes

This section introduces the calculation equations and the calculation process of the CO₂ emissions and the emission intensities.

2.1 Equation of CO₂ Emissions Calculation

$$CE_i = \sum_j EC_{ij} * CEF_j * CF_j \quad (1)$$

- CE_i is the CO₂ emissions of sector i
- EC_{ij} is the energy consumption of fuel type j in sector i
- CEF_j is the CO₂ emission factor of fuel type j
- CF_j is the conversion factor of fuel type j

2.2 Calculate the CO_2 emissions of each sector

The detail sectors comparison between Input-output table and the Statistical Yearbook is in the Appendix A.

- Sector 1, 2, 3, 7, 11, 13, 15, 17, 20-22, and 24-26: these sectors are the same in the I-O tables and Statistical Yearbook
- Sector 4, 5, 6, 8, 9, 10, 12, 14, 16, 18: aggregate the sectors in the Statistical Yearbook to get the CO_2 emissions of the corresponding sectors in the I-O tables
- Sector 27-29, 30-31, and 32-42: these sectors are aggregated into three sectors in the Statistical Yearbook. These sectors are assumed to have the same emission intensities as the three corresponding sectors
- Sector 23 (Production and Distribution of Electric Power and Heat Power): this sector is the one to be disaggregated into nine new energy sectors

* Since the production of this sector are used by all the other sectors, the total CO_2 emissions of sector 23 are proportionally disaggregated according to the proportion of intermediate input from sector 23 to all the other sectors

* Disaggregated/New energy sectors: calculate the proportion of CO_2 emissions of the new sectors according to the data from Lindner (2013), to get the final CO_2 emissions of each new sectors. Assume the CO_2 emissions are from the power generation sectors, the CO_2 emissions of the sector of Transmission and Distribution is assumed to be zero.

2.3 Calculate of the CO_2 emission intensity

- Direct CO_2 Emission Intensity

$$e_i = CE_i/X_i \tag{2}$$

X_i is the total output of sector i

- Total CO₂ Emission Intensity

$$t = e(I - A)^{-1} \quad (3)$$

- CO₂ Emission Intensity Matrix

$$T = \hat{e}(I - A)^{-1} \quad (4)$$

\hat{e} is the diagonalization matrix of e

The estimation results of the CO₂ emissions, direct emission intensities and the total emission intensities of each sector for both national China and Shanxi are showing in the Appendix B.

References

Lindner, S., J. Legault, and D. Guan (2013) Disaggregating the Electricity Sector of China's Input-Output Table for Improved Environmental Life-Cycle Assessment.

Economic Systems Research, 25, 300-320.

2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Energy,

Chapter 1, Introduction.

Appendix A Sectors comparison between I-O table and Statistical Yearbook

Sector	Input-Output Table	Statistical Yearbook
1	Farming, Forestry, Animal Husbandry and Fishery	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy
2	Mining and Washing of Coal	Mining and Washing of Coal
3	Extraction of Petroleum and Natural Gas	Extraction of Petroleum and Natural Gas
4	Mining and Processing of Ferrous Metal Ores	Mining and Processing of Ferrous Metal Ores
5	Mining and Processing of Non-Ferrous Metal Ores	Mining and Processing of Nonmetal Ores Mining of Other Ores
6	Manufacture of Foods, Beverages, and Tobacco	Processing of Food from Agricultural Products Manufacture of Foods Manufacture of Beverages Manufacture of Tobacco
7	Manufacture of Textile	Manufacture of Textile
8	Manufacture of Textile Wearing Apparel, Leather, Fur, Feather and Related Products	Manufacture of Textile Wearing Apparel, Footwear, and Caps Manufacture of Leather, Fur, Feather and Related Products
9	Processing of Timber, Manufacture of Wood, and Manufacture of Furniture	Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products Manufacture of Furniture
10	Manufacture of Paper and Paper Products, Printing, Reproduction of Recording Media and Manufacture of Articles For Culture, Education and Sport Activity	Manufacture of Paper and Paper Products Printing, Reproduction of Recording Media Manufacture of Articles For Culture, Education and Sport Activity
11	Processing of Petroleum, Coking, Processing of Nuclear Fuel	Processing of Petroleum, Coking, Processing of Nuclear Fuel
12	Manufacture of Raw Chemical Materials and Chemical Products	Manufacture of Raw Chemical Materials and Chemical Products Manufacture of Medicines Manufacture of Chemical Fibers Manufacture of Rubber Manufacture of Plastics
13	Manufacture of Non-metallic Mineral Products	Manufacture of Non-metallic Mineral Products
14	Smelting and Pressing of Ferrous Metals and Non-ferrous Metals	Smelting and Pressing of Ferrous Metals Smelting and Pressing of Non-ferrous Metals
15	Manufacture of Metal Products	Manufacture of Metal Products
16	Manufacture of General Purpose Machinery and Special Purpose Machinery	Manufacture of General Purpose Machinery Manufacture of Special Purpose Machinery
17	Manufacture of Transport Equipment	Manufacture of Transport Equipment
18	Manufacture of Electrical Machinery and Equipment	Manufacture of Electrical Machinery and Equipment
19	Manufacture of Communication Equipment, Computers and Other Electronic Equipment	Manufacture of Communication Equipment, Computers and Other Electronic Equipment
20	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work
21	Other Manufacturing	Manufacture of Artwork and Other Manufacturing
22	Recycling and Disposal of Waste	Recycling and Disposal of Waste
23	Production and Distribution of Electric Power and Heat Power	Production and Distribution of Electric Power and Heat Power
24	Production and Distribution of Gas	Production and Distribution of Gas
25	Production and Distribution of Water	Production and Distribution of Water
26	Construction	Construction
27	Transportation and Warehousing and Storage	Transport, Storage and Post
28	Postal Service	
29	Telecommunication, Computer Services and Software	
30	Wholesale and Retail Trade	Wholesale, Retail Trade and Hotel, Restaurants
31	Accommodation and Food Services	
32	Finance and Insurance	Others
33	Real Estate	
34	Rental and Leasing and Business Services	
35	Tourism	
36	Scientific Research	
37	Professional and Technical Services	
38	Other Services	
39	Education	
40	Health Care and Social Assistance	
41	Arts, Sports and Entertainment	
42	Government Services and Social Organization	

Appendix B Estimation results of CO₂ emissions, direct emission intensities and the total emission intensities

Sector	National China				
	Gross Output	CO ₂ Emissions	Direct CO ₂ Emission Intensity	Total CO ₂ Emission Intensity	
	(10 ⁴ Yuan)	(10 ⁶ ton)	(ton/10 ⁴ Yuan)	(ton/10 ⁴ Yuan)	
1	Farming, Forestry, Animal Husbandry and Fishery	488930000	154.10	0.32	1.25
2	Mining and Washing of Coal	96450530	383.52	3.98	6.37
3	Extraction of Petroleum and Natural Gas	95348874	127.25	1.33	3.06
4	Mining and Processing of Ferrous Metal Ores	61493459	79.61	1.29	4.07
5	Mining and Processing of Non-Ferrous Metal Ores	38516131	35.20	0.91	3.19
6	Manufacture of Foods, Beverages, and Tobacco	417903947	102.60	0.25	1.60
7	Manufacture of Textile	251973509	98.71	0.39	2.55
8	Manufacture of Textile Wearing Apparel, Leather, Fur, Feather and Related Products	180725774	17.57	0.10	2.00
9	Processing of Timber, Manufacture of Wood, and Manufacture of Furniture	109939306	29.55	0.27	2.40
10	Manufacture of Paper and Paper Products, Printing, Reproduction of Recording Media and Manufacture of Articles For Culture, Education and Sport Activity	149330075	99.82	0.67	2.98
11	Processing of Petroleum, Coking, Processing of Nuclear Fuel	210745642	60.59	0.29	3.06
12	Manufacture of Raw Chemical Materials and Chemical Products	619980926	742.46	1.20	4.26
13	Manufacture of Non-metallic Mineral Products	228043740	501.00	2.20	5.27
14	Smelting and Pressing of Ferrous Metals and Non-ferrous Metals	610959762	1555.06	2.55	6.43
15	Manufacture of Metal Products	177054748	79.90	0.45	4.41
16	Manufacture of General Purpose Machinery and Special Purpose Machinery	394865917	118.45	0.30	3.57
17	Manufacture of Transport Equipment	329784416	54.41	0.16	3.11
18	Manufacture of Electrical Machinery and Equipment	271550146	30.34	0.11	3.79
19	Manufacture of Communication Equipment, Computers and Other Electronic Equipment	411902530	41.79	0.10	2.55
20	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work	48796644	4.32	0.09	2.67
21	Other Manufacturing	61834239	18.94	0.31	2.86
22	Recycling and Disposal of Waste	43659772	2.10	0.05	0.37
23	Production and Distribution of Gas	11082895	34.19	3.09	5.85
24	Production and Distribution of Water	11788262	20.28	1.72	4.17
25	Construction	627217352	102.03	0.16	3.52
26	Transportation and Warehousing and Storage	317001113		1.00	2.49
27	Postal Service	7307574	426.41	1.00	2.35
28	Telecommunication, Computer Services and Software	100304221		1.00	2.09
29	Wholesale and Retail Trade	288325411	122.33	0.28	1.23
30	Accommodation and Food Services	148154357		0.28	1.50
31	Finance and Insurance	194810240		0.38	1.00
32	Real Estate	147746232		0.38	0.80
33	Rental and Leasing and Business Services	117845810		0.38	2.18
34	Tourism	13790171		0.38	2.10
35	Scientific Research	43970864		0.38	1.60
36	Professional and Technical Services	21582482	404.09	0.38	1.77
37	Other Services	87543772		0.38	1.89
38	Education	130658479		0.38	1.58
39	Health Care and Social Assistance	111225631		0.38	2.76
40	Arts, Sports and Entertainment	35409067		0.38	1.78
41	Government Services and Social Organization	158175717		0.38	1.51
42	T+D	141686948	0.00	0.00	3.82
43	coal power sub-c	91309366	839.40	9.19	13.01
44	coal super c	11649816	70.78	6.08	9.90
45	coal USC	8501217	29.49	3.47	7.29
46	wind	1889159	0.29	0.15	3.97
47	solar power	1574299	0.38	0.24	4.06
48	nuclear power	1889159	0.57	0.30	4.12
49	hydro power	52581601	5.23	0.10	3.92
50	natural gas power	3778319	5.23	1.38	5.20

Sector		Shanxi			
		Gross Output	CO ₂ Emissions	Direct CO ₂ Emission Intensity	Total CO ₂ Emission Intensity
		(10 ⁴ Yuan)	(10 ⁴ ton)	(ton/10 ⁴ Yuan)	(ton/10 ⁴ Yuan)
1	Farming, Forestry, Animal Husbandry and Fishery	4984000	506.21	1.02	4.28
2	Mining and Washing of Coal	17963581	6129.45	3.41	8.34
3	Extraction of Petroleum and Natural Gas	2514	0.00	0.00	1.28
4	Mining and Processing of Ferrous Metal Ores	568447	187.30	3.29	8.34
5	Mining and Processing of Non-Ferrous Metal Ores	328855	65.92	2.00	6.91
6	Manufacture of Foods, Beverages, and Tobacco	2726873	296.03	1.09	3.87
7	Manufacture of Textile	408736	66.87	1.64	6.58
8	Manufacture of Textile Wearing Apparel, Leather, Fur, Feather and Related Products	244068	7.76	0.32	5.13
9	Processing of Timber, Manufacture of Wood, and Manufacture of Furniture	190702	31.21	1.64	5.78
10	Manufacture of Paper and Paper Products, Printing, Reproduction of Recording Media and Manufacture of Articles For Culture, Education and Sport Activity	729101	124.47	1.71	6.99
11	Processing of Petroleum, Coking, Processing of Nuclear Fuel	10371034	431.62	0.42	4.90
12	Manufacture of Raw Chemical Materials and Chemical Products	5887056	4775.28	8.11	16.27
13	Manufacture of Non-metallic Mineral Products	4997491	2795.60	5.59	11.91
14	Smelting and Pressing of Ferrous Metals and Non-ferrous Metals	27982391	17651.78	6.31	13.20
15	Manufacture of Metal Products	2804275	236.58	0.84	9.74
16	Manufacture of General Purpose Machinery and Special Purpose Machinery	3836344	514.67	1.34	8.92
17	Manufacture of Transport Equipment	958708	265.92	2.77	11.26
18	Manufacture of Electrical Machinery and Equipment	846653	24.10	0.28	9.78
19	Manufacture of Communication Equipment, Computers and Other Electronic Equipment	69045	32.72	4.74	10.85
20	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work	140974	17.93	1.27	10.17
21	Other Manufacturing	191161	10.99	0.57	6.88
22	Recycling and Disposal of Waste	27629	2.92	1.06	3.15
23	Production and Distribution of Gas	298618	323.40	10.83	19.10
24	Production and Distribution of Water	143787	156.85	10.91	18.86
25	Construction	15248800	652.79	0.43	8.72
26	Transportation and Warehousing and Storage	6262300		1.69	4.08
27	Postal Service	160300	1432.15	1.69	5.31
28	Telecommunication, Computer Services and Software	2066900		1.69	4.45
29	Wholesale and Retail Trade	5158700	748.69	1.01	2.66
30	Accommodation and Food Services	2221300		1.01	3.21
31	Finance and Insurance	2772400		2.52	5.16
32	Real Estate	1587200		2.52	3.59
33	Rental and Leasing and Business Services	1765400		2.52	6.30
34	Tourism	259000		2.52	6.28
35	Scientific Research	509500		2.52	5.69
36	Professional and Technical Services	289700	4051.92	2.52	5.68
37	Other Services	1478200		2.52	4.14
38	Education	2127400		2.52	4.31
39	Health Care and Social Assistance	1413600		2.52	6.04
40	Arts, Sports and Entertainment	562200		2.52	5.63
41	Government Services and Social Organization	3294800		2.52	5.52
42	T+D	3636026	0.00	0.00	5.58
43	coal power sub-c	3421904	2101.05	6.14	11.72
44	coal super c	444403	182.16	4.10	9.68
45	coal USC	44440	18.91	4.25	9.83
46	wind	266642	0.92	0.03	5.61
47	solar power	0	0.00	0.00	0.00
48	nuclear power	44440	1.15	0.26	5.84
49	hydro power	177761	1.38	0.08	5.66
50	natural gas power	0	0.00	0.00	0.00