Supporting Information

for the research article:

Assessing Environmental Impacts Embodied in Manufacturing and Labor Input for the China-U.S. Trade

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1. Adjusting the China-U.S. trade data

Trade data between China and the U.S. are available from reputable statistics in both countries[1,2] which are integrated by United Nations Statistics Division (UNSD)[3]. However, there are obvious discrepancies between statistics in China and the U.S., as showed in Table S1. These discrepancies are due to differences in statistical rules. Without careful adjustment, choosing statistical trade data from either country will generate huge uncertainties.

Table S1 Bilateral trade statistics reported by China and the U.S. in billion U.S. dollars[3].

Year	Exports from China to the U.S.		Exports from the U.S. to China	
	Chinese data	U.S. data	Chinese data	U.S. data
2002	70.1	133.5	28.2	20.6
2003	92.6	163.3	33.9	28.4
2004	125.2	210.5	44.7	34.7
2005	163.2	259.8	48.7	41.8
2006	203.8	305.8	59.3	55.2
2007	233.1	340.1	69.5	65.2

Scholars have studied the statistical discrepancies in bilateral trade between the two countries and disclosed the underlying reasons. First, for exports from China to the U.S., the amounts from the U.S. statistics are much higher than the amounts from the Chinese statistics. This is mainly due to the re-exports through intermediate third destinations[4,5]. In particular, a great deal of Chinese goods is not directly exported to the U.S. from China ports, but first shipped to third destinations, primarily Hong Kong[6,7], and re-exported to the U.S. In the Chinese statistics, those re-exports are not recorded as exports to the U.S. but to Hong Kong. However, in the U.S. statistics, imports are recorded on a 'country of origin' basis which attributes the imports to the ultimate original country of production. Therefore, the re-exports through Hong Kong should be taken into account when studying pollution embodied in trade given that those re-exports are manufactured in China and finally consumed in the U.S. Although the statistics on re-exports through Hong Kong are available, scholars are still studying how to accurately estimate the markup of goods in terms of economic values[8]. In this study, however, we proposed a new approach to estimate the actual value of total exports from China to the U.S. by considering the quantity of goods. Despite there are markups for goods re-exported through Hong Kong, statistics in both China and the U.S. also record the quantities of goods in detail. Therefore, it is reasonable and straightforward to estimate the actual value of both direct and indirect exports by multiplying the quantity recorded in the U.S. and the unit value recorded in China.

Second, there are also statistical discrepancies for exports from the U.S. to China, although much smaller than those for exports from China to the U.S. Although China also compiles imports on the "country of origin" basis after 1993, studies pointed out that the tracing of ultimate origins by China customs may not entirely successful[4,8,9]. Therefore, it is necessary to adjust the U.S. exports to China for Hong Kong re-exports and markups. Moreover, the U.S. records export data on a "freight alongside ship (FAS)" basis, while China records import data on a "cost, insurance, and freight (CIF)" basis. This has instigated studies to estimate the cost of insurance and freight, primarily at an aggregated level. There are profound studies estimating the U.S. re-exports and markups to China via Hong Kong, which can be used to adjust the statistical discrepancies.

Exports from China to the U.S.

Exports from China to the U.S. are recorded by both countries, respectively, in a "free on board (FOB)" basis, officially known as "custom value" in the U.S., which excludes import duties, freight, insurance, and other charges beyond loading onto the cargo vessel. However, there are still huge differences between data reported by China and the U.S. The main reason is that data reported by China exclude the re-exports through Hong Kong while the U.S. records imports on the country of origin basis. Therefore, the differences between data of exports to the U.S. reported by the two countries are the re-exports from China to the U.S. through Hong Kong. This has instigated many studies to adjust official data from both countries by estimating re-export markups in Hong Kong most commonly by surveying Hong Kong middlemen[4,9,10,11]. Given that the accuracy of survey is hard to guarantee and products are dramatically different from each other, the drawback of surveying middlemen is obvious. In this research, a new approach is applied to adjust and balance the official data for exports from China to the U.S.

In fact, this proposed approach is enlightened by material flow analysis (MFA), a method commonly used by industrial ecologists to study sustainability by quantitatively tracing material flows in the economy[12]. In our case, it is also possible to adjust and balance data of exports from China to the U.S. by tracing the quantity of products. In particular, the real FOB value of eastbound trade from China to the U.S., expressed by $\boldsymbol{E}_{\mathbf{R}}$, can be computed by the following equation,

$$E_{\mathrm{R}} = \sum_{i=1}^{n} \left(\frac{V_{\mathrm{C}i}}{Q_{\mathrm{C}i}} Q_{\mathrm{U}i} \right) \quad (1)$$

where $\boldsymbol{V}_{\mathbf{C}i}$ and $\boldsymbol{Q}_{\mathbf{C}i}$ represent the value and quantity, respectively, of exported commodity in category i (i = 1, 2, …, n) reported by China, and $\boldsymbol{Q}_{\mathbf{U}i}$ indicates the same quantity reported by the U.S. The ratio of $\boldsymbol{V}_{\mathbf{C}i}$ to $\boldsymbol{Q}_{\mathbf{C}i}$ represents the FOB value of unit products in category i. Therefore, the real FOB value of exported commodity in this category can be computed by multiplying this ratio by $\boldsymbol{Q}_{\mathbf{U}i}$, the quantity reported by the U.S. on the country of origin basis which includes both direct exports from China and re-exports through Hong Kong. Data for $\boldsymbol{V}_{\mathbf{C}i}$, $\boldsymbol{Q}_{\mathbf{C}i}$, and $\boldsymbol{Q}_{\mathbf{U}i}$ are available from both countries' government statistics[1,3]. Moreover, the commodity classification systems used by China and the U.S. are both based on the Harmonized Commodity Description and Coding Systems (the Harmonized System or HS)[13]. Therefore there is no need to adjust commodity categories between databases from China and the U.S.

Although this novel method is straightforward in theory, there are several practical difficulties to be overcome. First, some commodities are not reported by the U.S. but reported by China. The reason is likely that those commodities are likely recorded into other categories by the U.S. Therefore, it is necessary to keep those commodities blank in the adjustment to avoid repetitive records. Second, there are also some commodities reported by the U.S. but not by China. Those are re-exports via Hong Kong and can be adjusted based on the U.S. data by estimated proportion of re-exported markups[9]. Third, for some commodities, trade values reported by the U.S. are less than those reported by China. This means such commodities are partially recorded by the U.S. into other categories. Therefore, the U.S. data are part of direct exports from China which can be directly used in the adjustment. Fourth, quantities of some commodities are not available from data reported by either China or the U.S. It is appropriate to use data reported by China in the adjustment because only few commodities fall into such case. Finally, all other commodities' adjusted trade values can be computed by the equation (**1**).

In this research, exports from China to the U.S. are adjusted based on the UNSD database at the level of HS 6 digits for year 2002 through 2007 using the method described above. Table S2 compares the adjustment result with official statistical data and other studies. The adjustment results of this research are between official statistical data reported by China and the U.S. and closer to the U.S. data. Compared with other top-down estimations, our results are slightly higher or close to their upper bound. It is hard to determine which estimation approximates the reality better. However, the adjustment in this research investigates the bilateral trade between China and the U.S. from a bottom-up perspective which is closer to the actual trade activities. Moreover, the adjustment in this research does not only contain the total trade data, but also the sectoral data as disaggregated as the HS 6 digits level which is essential for IOA related studies.

Table S2 Adjustment of Chinese exports to the U.S. and comparison in billion U.S. dollars.

Year	Official Chinese data[3]	Official U.S. data[3]	Adjustment of this research	Fung *et al.*[9]	Schindler and Beckett[5]
2002	70.1	133.5	113.0	94.5~109.5	95.3
2003	92.6	163.3	146.3	116.5~135.6	117.8
2004	125.2	210.5	172.3	149.9~175.4	N/A
2005	163.2	259.8	207.0	189.7~219.5	N/A
2006	203.8	305.8	282.9	N/A	N/A
2007	233.1	340.1	289.9	N/A	N/A

Exports from the U.S. to China

There are two steps to adjust statistical data for exports from the U.S. to China. First, the export data to China reported by the U.S. are on an FAS basis which excludes the costs of loading the goods onto the cargo vessels at the origination ports. Therefore, it is necessary to make data comparable by converting them into the same basis. Because loading goods for export is part of the domestic economic activities, it is reasonable to include such costs into the values of goods as FOB value does, especially when investigating the economy's input-output structure. In order to convert into the FOB values, the U.S. reported export data on the FAS basis are adjusted by adding 1%, which has been proposed by researchers at various international organizations, including the World Bank[9]. On the other hand, China reports import data on the basis of CIF which includes insurance and freight costs. To adjust into FOB values, CIF values are multiplied by factors provided by Ferrantino and Wang[8]. Table S3 shows the adjusted total exports data reported by the U.S. in FOB value. Detailed data in commodity level are also available.

Table S3 Adjustment for the data of U.S. exports to China into FOB values in billion U.S. dollars.

Year	Chinese Data (in CIF value)	FOB/CIF[8]	Adjusted Chinese Data (in FOB value)	U.S. Data (in FAS value)	Adjusted U.S. Data (in FOB value)
2002	28.2	0.962	26.3	20.6	20.8
2003	33.9	0.959	32.5	26.7	27.0
2004	44.7	0.960	42.9	32.6	32.9
2005	48.7	0.961	46.8	38.7	39.2
2006	59.3	0.961	57.0	51.6	52.1
2007	69.5	0.961[a]	66.8	60.3	60.9

a: Ratio for 2007 is not available. Here use 0.961 the same as the ratios for 2005 and 2006.

Second, further adjustment is required by taking the U.S. re-exports to China through Hong Kong into account. Although China has been recording their imports on the "country of origin" basis since 1993, studies indicated that China's tracing of ultimate origins may not entirely successful[4,8,9]. Therefore, the method developed in this research cannot be applied here to identify Hong Kong re-exports for the U.S. exports to China. Due to lack of data, it is also hard to directly trace Hong Kong re-exports by distinguishing both origins and destinations in commodity level. Given that Hong Kong re-exports only take about 20% of the U.S. direct exports to China since 2002 and the proportions of re-exports have been decreasing steadily[8,9], it is appropriate to adjust the U.S. exports to China data in commodity level by adding the share of Hong Kong re-exports and markups. In particular, the real westbound trade from the U.S. to China, expressed by $\boldsymbol{W}_{\mathbf{R}}$, can be computed by the following equation,

$$W_{\mathrm{R}} = \sum_{i=1}^{n} \left(V_{\mathrm{U}i} + \frac{V_{\mathrm{U}i} p_{\mathrm{r}}}{1 + p_{\mathrm{m}}}\right) \qquad (2)$$

where $\boldsymbol{V}_{\mathbf{U}i}$ represents the U.S. reported FOB value of exported commodity in category i ($i = 1, 2, \ldots, n$), $\boldsymbol{p}_{\mathbf{r}}$ is percentage of Hong Kong re-exports of $\boldsymbol{V}_{\mathbf{U}i}$, and $\boldsymbol{p}_{\mathbf{m}}$ indicates the percentage of markups of Hong Kong re-exports. Table S4 represents the adjustment of Hong Kong re-exports and markups based on the U.S. data in FOB value. Detailed data in commodity level are also available. Given that the adjustment based on the U.S. data is straightforward and represents the real exports to China, it is proper to be used as the approximation of the real U.S. exports to China in FOB value.

Table S4 Adjustment for the data of U.S. exports to China in FOB value by taking Hong Kong re-exports and markups into account, in billion U.S. dollars.

Year	Adjusted Chinese Data in FOB value	Adjusted U.S. Data in FOB value	Percentage of Hong Kong re-exports as direct U.S. exports to China (%)[8]	Percentage of Hong Kong re-export markups (%)[9]	Adjusted U.S. data including Hong Kong re-exports
2002	26.3	20.8	22.8	12.8	24.9
2003	32.5	26.7	18.4	11.2	31.4
2004	42.9	32.9	13.0	10.1	36.8
2005	46.8	39.2	12.4	10.1	43.6
2006	57.0	52.1	12.4	10.1[b]	58.0
2007	66.8	60.9	12.4[a]	10.1[b]	67.7

a: Percentage for 2007 is not available. Here use 12.4% the same as the ratios for 2005 and 2006;

b: Percentage for 2006 and 2007 are not available. Here use 10.1% the same as the ratio for 2005.

2. Energy and CO_2 intensities of individual consumption in China and the U.S.

Table S5 presents these values used in this research. There are other studies providing similar data which are used in this study for analyzing uncertainties.

Table S5 Annual energy use and CO_2 emissions of average resident.

Impact	Unit	Area	China	U.S.
Direct energy	GJ/ca	Urban	4.71	103.70
		Rural	2.50	
Total energy	GJ/ca	Urban	16.21	309.99
		Rural	3.52	
Direct CO_2	t/ca	Urban	0.39	8.17
		Rural	0.34	
Total CO_2	t/ca	Urban	1.48	20.22
		Rural	0.35	
Source			[14]	[15]

3. CO2 embodied in the 2002 China-U.S. trade

Figure S1 compares the embodied CO_2 in the manufacturing of unit commodities in China and the U.S. Not surprisingly, products manufactured in China generate more CO_2 than those in the U.S. Particularly, not only for the manufacturing of unit transportation equipment, electric equipment, and other equipment, CO_2 emitted in producing unit nonmetal products and electronic equipment in China is about ten times of that in the U.S. as well.

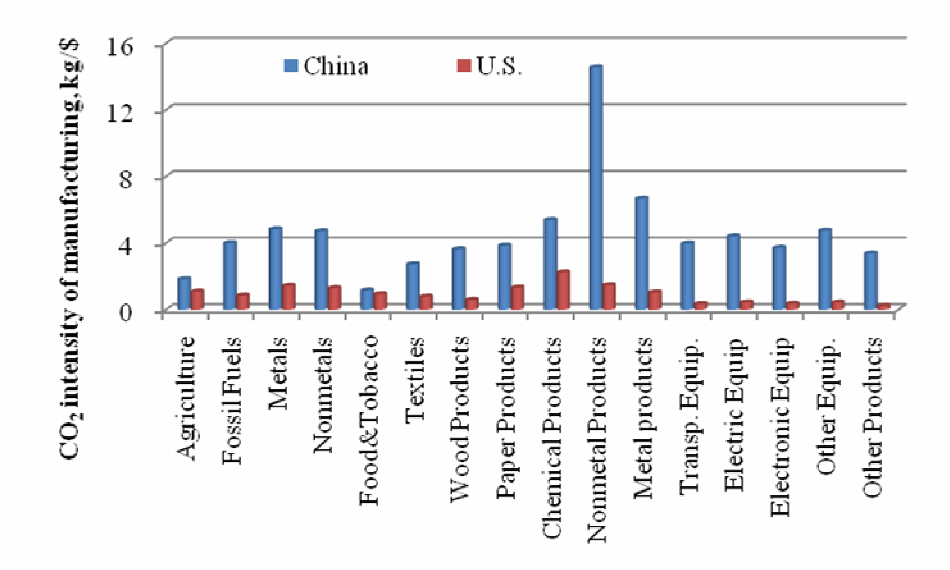

Figure S1 Comparison of CO_2 embodied in the manufacturing of unit commodities in China and the U.S.

Figure S2 shows the comparison of CO_2 EOLI embodied in unit commodities in China and the U.S. Similarly, CO_2 EOLI embodied in most of commodities is in the same magnitude for China and the U.S., except in agriculture products.

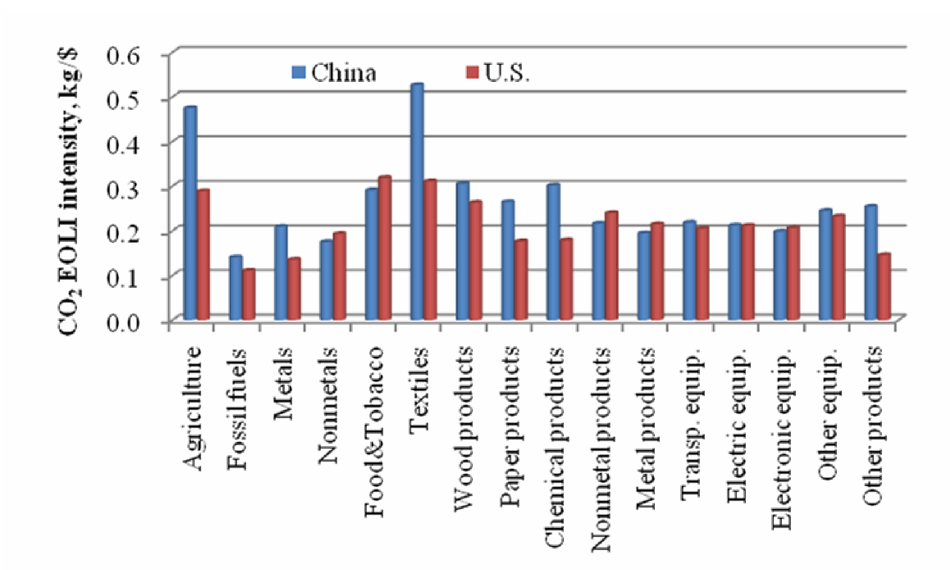

Figure S2 Comparison of CO_2 EOLI embodied in unit commodities in China and the U.S.

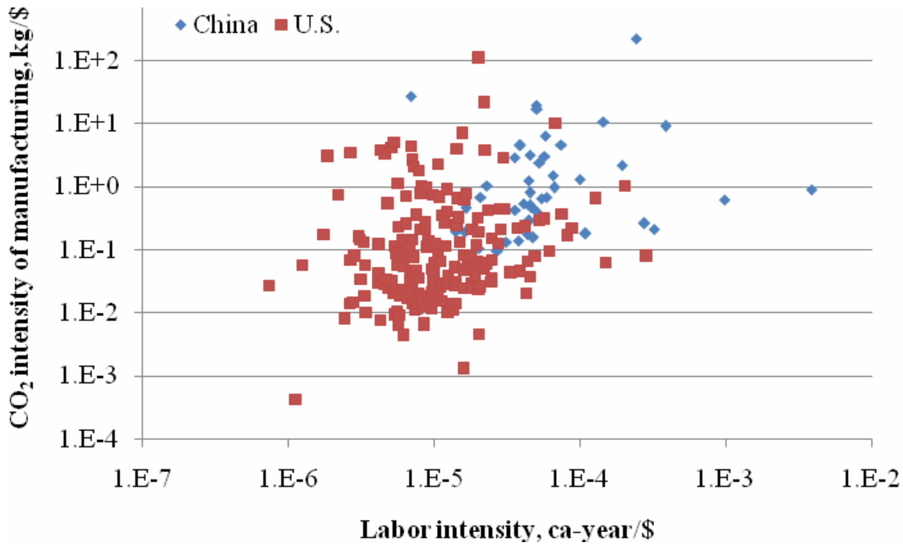

Figure S3 The correlation between CO_2 and labor embodied in per unit economic output of each sector for China and the U.S. in 2002.

Figure S4 shows CO_2 embodied in the manufacturing of the 2002 China-U.S. trade. The CO_2 embodied in eastbound trade, 405.08 Mt, is 11.29% of the total CO_2 generated by China in 2002, while the CO_2 embodied in westbound trade, 20.02 Mt, is only 0.46% of the total figure in the U.S. In particular, CO_2 embodied in textiles, electronic equipment, and other equipment take 51.70% of the total CO_2 embodied in the eastbound trade. Chemical products contribute the most, accounting for 44.41%, for the CO_2 embodied in the westbound trade.

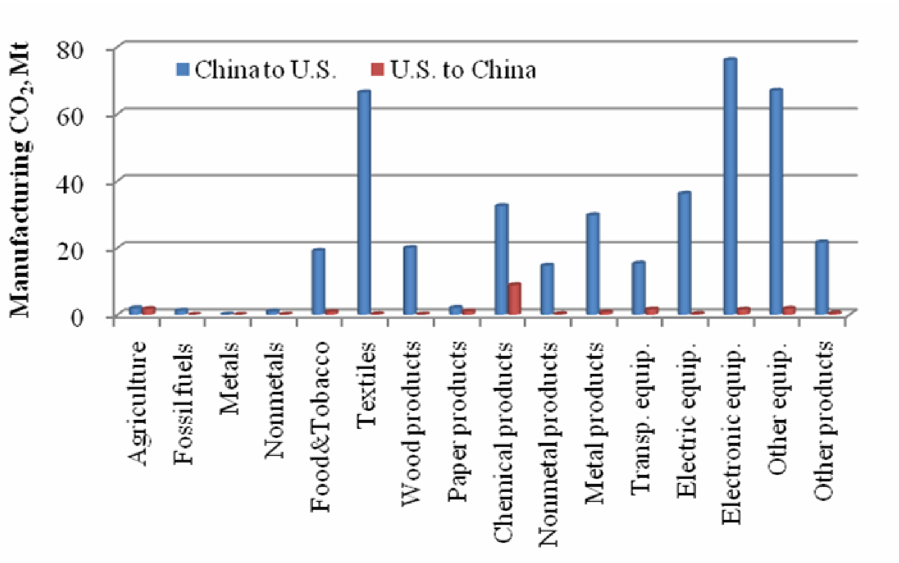

Figure S4 CO_2 embodied in the manufacturing of the 2002 China-U.S. trade.

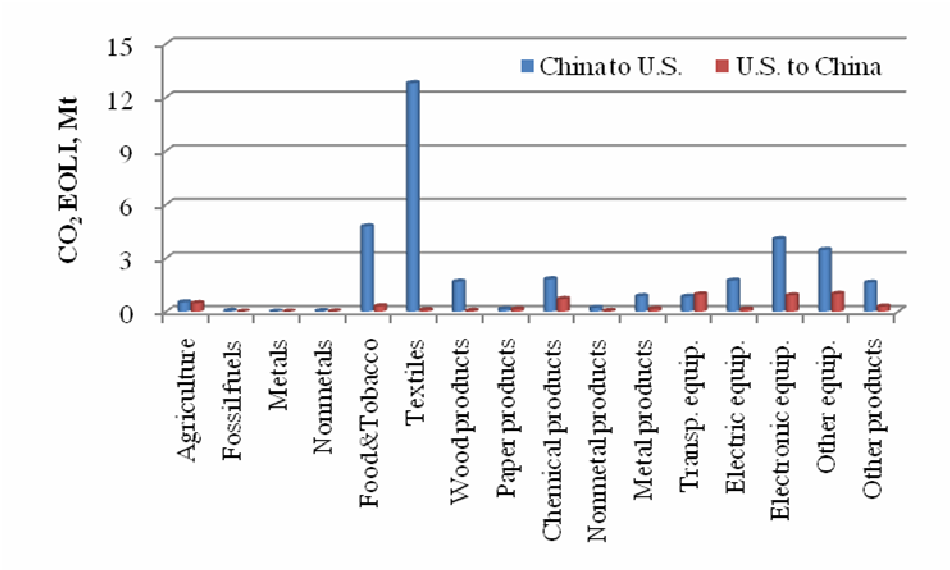

Figure S5 CO_2 EOLI embodied in the 2002 China-U.S. trade.

Figure S5 shows CO_2 EOLI embodied in the 2002 China-U.S. trade. Overall, Chinese workers' consumption generates totally 36.36 Mt CO_2 due to the 2002 bilateral trade, while 5.29 Mt is emitted on the U.S. side. In average, one dollar exports by China can cause totally 0.32 kg CO_2 due to workers' consumption, while the U.S. exports of one dollar lead to 0.21 kg CO_2 EOLI. Textiles, food and tobacco, and electronic equipment take the lead in the eastbound trade in terms of CO_2 EOLI, representing 59.53% of the total figure. For the westbound trade, other equipment, transportation equipment, and electronic equipment take 54.36% of the CO_2 EOLI.

4. Preliminary comparison of energy use and CO_2 emissions embodied in the manufacturing and labor input of products and services in China and the U.S.

Table S6 Preliminary comparison of energy use and CO_2 emissions embodied in the manufacturing and labor input of products and services in China and the U.S.

Sector	Energy, MJ/$		CO_2, kg/$	
	China	U.S.	China	U.S.
Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy	23.3	36.2	1.5	2.1
Coal Mining and Dressing	667.0	242.0	21.8	12.3
Petroleum and Natural Gas Extraction	1423.4	80.8	51.0	4.4
Ferrous Metals Mining and Dressing	351866.3	796.1	10972.6	28.1
Nonferrous Metals Mining and Dressing	1781.1	197.1	42.0	8.0
Nonmetal Minerals Mining and Dressing	417.6	96.1	14.5	5.4
Other Minerals Mining and Dressing	27527.3	1047.4	2906.9	53.4
Logging and Transport of Wood and Bamboo	96497.8	60.0	5683.9	4.0
Food Processing	20.6	9.1	0.8	0.5

Food Production	15.0	4.3	0.6	0.2
Beverage Production	16.3	2.5	0.8	0.1
Tobacco Processing	5.2	0.7	0.2	0.0
Textile Industry	37.0	27.0	1.1	1.3
Garments and Other Fiber Products	4.5	1.4	0.2	0.1
Leather, Furs, Down and Related Products	5.1	8.9	0.2	0.5
Timber Processing, Bamboo, Cane, Palm Fiber & Straw Products	86.9	142.2	3.5	4.0
Furniture Manufacturing	8.2	5.5	0.3	0.3
Papermaking and Paper Products	484.3	117.8	16.7	3.1
Printing and Record Medium Reproduction	213.6	92.4	7.0	4.9
Cultural, Educational and Sports Articles	6.8	2.0	0.2	0.1
Petroleum Processing and Coking	916.8	55.0	19.0	3.3
Raw Chemical Materials and Chemical Products	641.5	52.2	25.1	2.6
Medical and Pharmaceutical Products	28.0	3.1	0.9	0.2
Chemical Fiber	27477.7	92.3	345.6	3.8
Rubber Products	57.2	16.2	1.4	0.8
Plastic Products	63.9	29.9	1.2	1.3
Nonmetal Mineral Products	444.3	116.1	78.2	11.8
Smelting and Pressing of Ferrous Metals	5984.5	613.4	442.4	40.1
Smelting and Pressing of Nonferrous Metals	933.0	153.8	18.6	7.4
Metal Products	52.1	34.4	1.4	1.8
Ordinary Machinery	30.3	4.1	1.2	0.2
Equipment for Special Purposes	11.7	3.2	0.5	0.2
Transportation Equipment	13.4	2.6	0.4	0.1
Electric Equipment and Machinery	9.0	5.8	0.3	0.3
Electronic and Telecommunications Equipment	4.8	3.4	0.1	0.2
Instruments, Meters, Cultural and Office Machinery	8.9	6.9	0.3	0.4
Other Manufacturing Industry	34.0	2.1	0.7	0.1
Production and Supply of Electric Power, Steam and Hot Water	26.9	296.6	205.4	23.3
Production and Supply of Gas	133.7	2.9	4.4	0.2
Production and Supply of Tap Water	376.0	28.8	0.9	0.3
Construction	18.5	5.8	0.4	0.4
Transportation, Storage, Post and Telecommunication Services	79.5	47.5	5.8	3.0
Wholesale, Retail Trade and Catering Services	16.1	7.3	0.9	0.4
Others	9.6	4.7	0.6	0.3

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