Industrial Structure Change and CO_2 Emission Associated with Infrastructure Development in China

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The infrastructure investment of China increased rapidly last decades, especially from 2002 to 2007. This arose to industrial structure change, a larger number of material consumption and CO_2 emission. This paper investigated the features and recent changes of China's industrial structure and CO_2 emission associated with infrastructure development using input-output tables for different periods from 1992 to 2007. We found the infrastructure industries and material industries increased at the sample period, especially from 2002 to 2007. In addition, the study of industrial repercussion effect showed Construction sector exhibited the largest backward linkage effect after 1997 and it increased always. The forward linkage effect of Material sectors, such as Steel and Iron Products, Non-Metallic Products and Chemicals increased. This indicated infrastructure construction promoted the development of other material products sectors. Lastly, we calculated CO_2 emission of each sector and the results indicated the CO_2 emission induced by capital formation in Construction sector is far more than other sectors and it increased, especially from 2002 to 2007. The indirect CO_2 emission is far higher than direct CO_2 emission for all sectors, thus, the related sectors must be also considered when improving energy efficient of one sector.

Key Words : *Infrastructure construction, Industrial structure, CO2 emission*

1. INTRODUCTION

Since the start of economic reform in 1979, China has experienced spectacular economic growth. Its gross domestic product (GDP) has increased at average growth rate of 9.79% annually over the period 1980–2003[1)]. China's long-term social and economic development goal is to reach GDP of USD 4 trillion (constant 2000 price) by 2020, which would quadruple per capita GDP of 2000. To achieve this goal, the GDP would increase at a rate of 7.2% per annum between 2000 and 2020[2)]. At the same time, the rapid economic growth has come at the expense of the environment. China's CO_2 emissions increased from 1460 million tons (Mt) in 1980 to 6499 Mt in 2007[3)]. Within a very short period of time, from 2002 to 2007, China's CO_2 emissions doubled and it is now believed that China is the world's biggest emitter of CO_2[4)]. It has raised the concern of energy analysts and policy makers.

Recently years, China implemented the policies of increasing infrastructure construction and expanding domestic demand to keep the economic growth. Especially after 2002, infrastructure investment of China increased rapidly, which arose to industrial structure change, a larger number of material consumption and CO_2 emission. Furthermore, each sector indirectly consumed

amounts of energy induced by the final demand except direct consumption in the production. So the indirect energy consumption of each sector should be considered when improving energy efficiency. Therefore, it is very significant to investigate the features of industrial structure as well as each sectoral CO_2 emission change associated with infrastructure development in China, especially from 2002 to 2007.

In this regard, the input-output table (IO table hereafter) is extremely useful and informative. It provides systematic descriptions of the input-output structures between industries and enables quantitative analysis of industry structure, inter-industry relationships and their development. Regarding to industrial change of China, A. Y. Liu studied the sources of structural change and output growth of China's economy for 1987-1992[5]. J. Teng[6] and Q. Li[7] analyzed industrial structure of China for 1987-1992 and 1983-1995. Q. Y. Hu[8] analyzed the economic structure for 1987-1997 and compared with industry development and mature stage of Japan, but he did not analyze the relation between demand structure and industrial structure. Furthermore, input output model is used generally to study the energy consumption and CO_2 emission in China. X, B, Liu analyzed CO_2 emission embodied in Japan–China trade[9]. B. Q. Lin evaluated CO_2 emissions in international trade of China[10]. H. T. Liu studied the household indirect energy consumption and impacts of alternative energy policies in China by input–output analysis[11].

Studies mentioned above did not include the recent data, especially 2007 input-output table. Furthermore, few studies referred to the features of industrial change and CO_2 emission accompanied with infrastructure development.

The main objectives of this paper are to:

- study the features of infrastructure investment recent years in China.
- investigate the features and recent changes for China's industry structure and inter-industry relationships degree especially for infrastructure industries.
- investigate the direct and indirect CO_2 emission change of each sector with industrial structure change.
- assess the potential impact of increase infrastructure construction on national CO_2 emissions.

2. DATA AND METHODOLOGY

(1) Data

The main sources of data used in this study are Chinese IO tables for 1992, 1997, 2002 and 2007, released by the Office of Input-Output Survey, China State Statistical Bureau (SSB). Other sources include China Statistical Yearbook (various issues) and China Energy Statistical Yearbook (various issues).

The selection of the period for the analysis is based on two criteria: (1) the period between which the comparison is made should reflect the distinguishing phases and impacts of policy changes on the economy over this period; (2) these tables have to be constructed using the identical industrial classification and the same method.

I-O table is aggregated into 11 sectors according to the relationship between each sector and construction sector. Like most IO tables, all those four tables were constructed at the current year price. It is therefore essential and necessary to consolidate the inter-industry transactions data on a uniform basis (2002).

(2) Analysis of industrial repercussion effect

Generally, the development of one industry will use other products and drive the development of other industries. Likewise, this industry will be used to other industries as the intermediate input. A. O. Hirschman developed the concepts of backward and forward linkages as a means of identifying "key sectors" for industrial investment strategies and determining which sector of the economy should be expanded or contracted. Backward linkages show the relationship of inter-industry purchases to total purchases, while forward linkages show the relationship of inter-industry sales to total output[12]. In this study, we investigate the repercussion effect of each industry associated with infrastructure development by using forward linkage effect and backward linkage effect indicators and they can be measured respectively as follows:

$$F_i = \sum_j b_{ij} \Big/ \frac{1}{n}\left(\sum_i \sum_j b_{ij}\right) \quad (1)$$

where F_i is the forward linkage effect of j sector. It is the supply amount of sector i when other sectors increased 1 unit final demand. b_{ij} is element of the Leontief inverse matrix $(I\text{-}A)^{-1}$.

$$B_j = \sum_i b_{ij} \Big/ \frac{1}{n}\left(\sum_j \sum_i b_{ij}\right) \quad (2)$$

where B_j is the backward linkage effect of i sector. It is the output amount of other sectors when sector j increased 1 unit final demand.

(3) Estimating direct and indirect CO_2 emission

In this paper, the direct CO_2 emission can be estimated as follows:

$$C_{j,\,dir} = e_{j,\,dir} \times X_j \times CO_2\ coefficient \quad (3)$$

where $C_{j,dir}$ is direct CO_2 emission of j sector. $e_{j,dir}$ is the direct energy consumption per unit of output in j sector. X_j is the total output of j sector. *CO_2 coefficient* is corresponding CO_2 emission coefficient of energy[13].

Productions of various commodities are ultimately geared towards meeting final demands, and they generate CO_2 emissions due to the direct and indirect use of fossil fuels. As an example, for the railway construction, direct emissions occur due to the use of fossil fuels in the railway-construction sector itself. Indirect emissions in railway construction occur due to the use of inputs such as steel, whose production itself would have generated emissions. The steel sector in turn uses iron-ore and coal, the production of which involves use of fossil fuel, and so on. The indirect emissions in the production of one unit of final demand of a sector j can be estimated as:

$$e_{j,ind} = \sum_{i}^{n} e_{i,dir} \times b_{i,j} \quad (4)$$

where b_{ij} is element of the Leontief inverse matrix $(I\text{-}A)^{-1}$. b_{ij} represents the amount of output from sector i required directly and indirectly to produce per unit final demand from sector j.

Finally, the indirect CO_2 emission induced by the final demand of j sector can be estimated as:

$$C_{j,ind} = e_{j,ind} \times F_j \times CO_2\ coefficient \quad (5)$$

where F_j is the final demand of j sector. *CO_2 coefficient* is corresponding CO_2 emission coefficient of energy.

The final demand in the IO model includes household consumption, government consumption, gross capital formation and net export. In this study, the CO_2 emission induced by the capital formation of each sector is also estimated as follows:

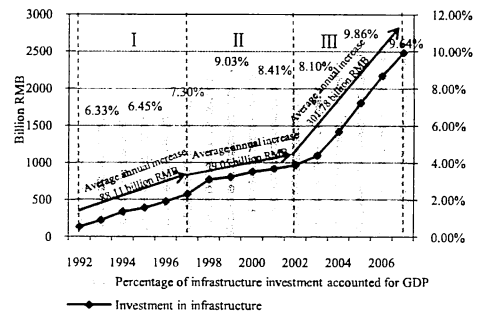
$$C_{j,c} = e_{j,ind} \times C_j \times CO_2\ coefficient \quad (6)$$

where C_j is gross capital formation of j sector.

3. RESULTS AND DISCUSSIONS

(1) Infrastructure investment in China

The infrastructure investment can increase employment, decrease negative effects of economic crisis, stimulate domestic consumption and drive economic increase. Figure 1 is the infrastructure investment situation in China. It shows that both the infrastructure investment and the percentage of which accounted for GDP increased from 1992 to 2007. The annual average increase of infrastructure investment at the second stage is 79.05 billion RMB, and it is the least compared with the first and third stage. For the third stage, both the infrastructure investment and percentage of which accounted for GDP increased dramatically and they are higher than other two stages, which indicates China reinforced relatively infrastructure investment from 2002 to 2007. This is because the tenth five-year plan (2001-2005) was heavily focused on building roads, rail network, bridges, ports and airports. At the end of 2004, the Chinese government removed strict regulations on foreign investments in infrastructure. This led large numbers of foreign investors invested in infrastructure projects. During 2004-2008, China witnessed significant growth in infrastructure projects during the preparations for Olympic Games in Beijing[14].



Source: Calculated by China Statistical Yearbook

Notes: (1) The infrastructure in this study include Electricity, steam, hot water production and supply sector, Transportation & telecommunication sector and Water conservancy sector. (2) I , II and III denotes three stage of investment in infrastructure respectively.

Fig. 1 Infrastructure investment in China

(2) Industrial structure change of China

We first examine China's industry structure and its recent changes using IO tables. By simply looking at each industry's share of the total output as shown in Figure 2, we can identify the following three prominent characteristics of China's economic structure.

Firstly, China's industry structure has recently been experiencing considerable change. Specifically, the relative size of tertiary industry has been on the rise from 1992 to 2002, but it did not exhibit the obvious change after 2002. The primary industry has been on the decline.

Secondly, the infrastructure industries, Electric power, gas, water production and supply sector and Transportation & telecommunication sector increased dramatically after 1992. In addition, Transport equipment also increased, especially after 1997. This is because China government increased the infrastructure investment, especially to transportation sector, which arise increase

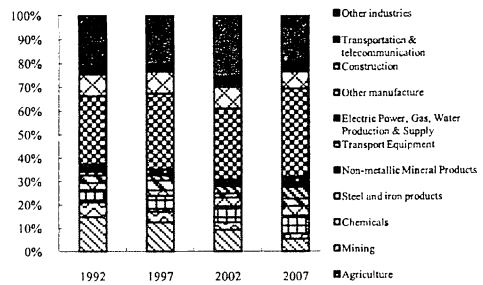
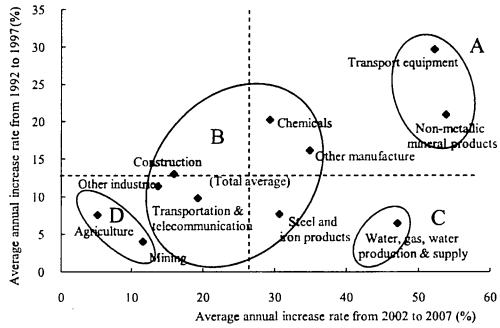


Fig. 2 Each sector's share of the total output



Notes: (A) Growing industries, (B) Mature industries, (C) Developing industries, (D) Declining industries. Dashed lines represent the average of all sectors.

Fig. 3 Average annual increase rate of output to each sector

of demand to transport equipment.

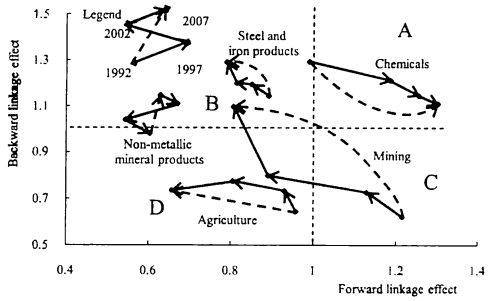
Thirdly, the infrastructure construction consumed a large number of materials. Figure 2 shows the Steel and iron products sector has been on the obvious rise. However, the share of Non-metallic mineral products sector increased up to 1997 and suddenly decreased in 2002. Two causes can be considered: (1) Figure 2 is the each sector's share of the total output, which is relative value, the output of Non-metallic mineral products increased at the sample period. In addition, from Figure 1 we can see the annual average increase of infrastructure from 1997 to 2002 is lowest, which arouse the decrease of share of non-metallic mineral products. (2) Ministry of environmental protection of China promulgated and implemented Technological Policy for Treatment of Municipal Solid Wastes and Its Pollution Control[15]. A great quantity of solid waste, especially construction waste was recycled and demand of non-metallic products was decreased.

(3) Industrial characteristic classified by the average annual increase rate of output to each sector in China

Figure 3 is the annual average increase rate of output to each sector, and they were classified into growing industries, mature industries, developing industries and declining industries according to the average annual increase rate of different stages. Figure 3 shows the output of Transportation equipment and Non-metallic products sector increased at the two stages, so they are growing industries. The average annual increase rate of Electric power, gas, water production and supply sector from 2002 to 2007 is much higher than which from 1992 to 1997, so it is developing industry. This is consistent with the analysis before. The infrastructure industry increased with the increase of infrastructure investment. Furthermore, infrastructure construction obviously led to the development of other industry, especially material industries. Figure 3 shows the average annual increase rate of group B did not exhibit the obvious change, so they are mature industries. The average annual increase rate Agriculture and Mining are far lower than the average of all sectors, so they are declining industries.

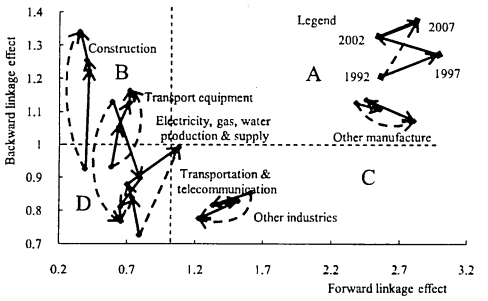
(4) Analysis of industrial repercussion effect

Figure 4 and Figure 5 are changes of backward and forward linkage of each sector from 2002 to 2007. Furthermore, the industries are classified into A (High backward effect – high forward effect), B (High backward effect – low forward effect), C (Low backward effect – high forward effect), and D (Low backward effect – low forward effect) industry. As shown in Figure 4 and Figure 5, Chemicals and Other manufactures are High backward effect – high forward effect industries. So they are the important sector promoting the economic growth. The forward linkage effect of Construction sector did not change basically, but the backward linkage effect increased from 1992 to 2007 and Construction sector exhibited the highest backward linkage effect after 1997. Generally, when a house is built, as many as 2500 types of materials are consumed, which mainly come from the industry of construction materials, metallurgy, chemistry, forest, machinery, etc[16]. Because the infrastructure rapidly developed, especially after 2002, which consumed amounts of materials and led the backward linkage effect of Construction sector increased over the sample period. The infrastructure industries, such as Electric power, gas, water production and supply sector and Transportation & telecommunication sector exhibited low forward linkage effect and high backward linkage effect which increased from 1992 to 2007. The development of infrastructure will drive the development of material manufacture and the service industry. Regarding to the material industry, Steel and iron products sector and Non-metallic mineral products sector, their backward linkage effect decreased and forward linkage



Notes: (A) High backward effect– high forward effect, (B) High backward effect – low forward effect, (C) Low backward effect – high forward effect, (D) Low backward effect – low forward effect.

Fig. 4 Repercussion effect of each industry



Notes: (A) High backward effect– high forward effect, (B) High backward effect – low forward effect, (C) Low backward effect – high forward effect, (D) Low backward effect – low forward effect.

Fig. 5 Repercussion effect of each industry

effect increased. Because the products of these sectors are used to other sectors as the raw material, so their forward linkage effect from other sectors increased. This indicated infrastructure construction promote the development of other industry. Thus, the policy of increasing infrastructure construction to expand domestic demand is very important to economic stabilization and deal with the international economic situation, such as economic crisis, at the industrial development stage.

(5) CO_2 emission of different sector in China

Using the physical energy balance table, we calculated distribution of CO_2 emission in different sectors (Table 1). The results show that the direct CO_2 emission concentrated in Steel and iron products, Other manufactures, Non-metallic mineral products and Chemicals from 1992 to 2007. Especially, the direct CO_2 emission of Steel and iron products sector increased more than 1 time, which accounts for 28.95% of total CO_2 emission in 2007. This is because the infrastructure investment in China increased rapidly from 2002 to 2007 and a large amount of steel and iron products was consumed in this period. In addition, the increasing of possession quantity of cars in China, so the direct CO_2 emission of Transportation and telecommunication sector also increased at the sample period. Regarding to the CO_2 emission induced by the final demand of each sector, the Other manufactures sector consumed large amount of intermediate products in production process, so it exhibited the highest CO_2 emission, which increased rapidly from 2002 to 2007. The second highest CO_2 emission was found in construction. Table 1 also shows the CO_2 emission of Construction sector induced by capital formation is far more than other sectors and they increased, especially from 2002 to 2007. This is because China implemented the policies of increasing infrastructure construction and expanding domestic demand to keep the economic increasing. As shown in Figure 5, Construction

Table 1 Direct and indirect CO_2 emission in different sectors

	1992			1997			2002			2007		
	C_{dir} (Mt)	C_{ind} (Mt)	C_c (Mt)	C_{dir} (Mt)	C_{ind} (Mt)	C_c (Mt)	C_{dir} (Mt)	C_{ind} (Mt)	C_c (Mt)	C_{dir} (Mt)	C_{ind} (Mt)	C_c (Mt)
Agriculture	68.92	149.46	11.83	80.24	172.20	15.48	87.20	127.90	11.57	113.68	92.75	13.33
Mining	83.02	5.82	4.67	110.14	17.58	0.78	132.44	20.94	4.35	165.82	14.22	3.01
Chemicals	230.77	43.68	15.85	293.27	143.76	20.35	236.94	111.36	7.01	374.52	179.41	8.69
Steel and iron products	234.45	0.84	-57.71	417.25	2.10	-38.24	416.58	11.13	-1.17	964.42	178.79	20.34
Non-metallic Mineral Products	226.90	38.05	8.21	268.91	68.60	19.09	253.60	51.56	-9.09	338.75	49.69	1.48
Transport Equipment	9.26	28.05	45.15	16.55	102.42	70.37	12.92	91.49	63.35	19.32	218.72	140.23
Electric Power, Gas and Water Production and Supply	12.63	5.79	0.00	78.28	23.00	0.00	53.20	25.05	0.34	63.97	29.05	0.05
Other manufactures	321.98	567.41	170.87	366.96	961.11	217.72	416.53	985.97	243.70	453.58	1690.60	415.35
Construction	23.41	414.34	414.34	16.45	616.91	616.01	24.12	678.36	675.77	64.59	1090.85	1066.55
Transportation and telecommunication	98.88	58.85	3.57	138.29	53.25	4.26	206.29	92.31	6.22	390.63	151.84	5.33
Other industries	399.01	467.76	36.22	381.93	539.41	18.58	401.06	659.39	32.63	381.87	709.28	50.09
Total	1709.23	1780.05	653	2168.27	2700.34	944.4	2240.88	2855.46	1034.68	3331.15	4405.2	1724.45

Notes: C_{dir}, C_{ind} and C_c represents direct CO_2 emission, indirect CO_2 emission and CO_2 emission induced by capital formation respectively.

sector exhibited the strongest forward linkage effect. In the construction process, Construction sector consumed a large amount of materials which consumed plenty of energy in the production process, so the indirect CO_2 emission of Construction sector is much larger than direct CO_2 emission. Table 1 also shows the indirect CO_2 emission of most of sectors, especially mining, steel and iron products, non-metallic mineral products was higher than the direct CO_2 emission. This is because these sectors are raw material industries and their products were used to other sectoral production.

Regarding to the amount of CO_2 emission in China, Xu's study indicated it is 1110.6 Mt (million tons) in 2002 according to the CO_2 emission of Chinese energy[17]. China energy report 2008[18] and IEA[19] (International energy agency) shows the CO_2 emission of China is 5423 Mt and 6071.2 Mt in 2007 respectively. In this paper, the total direct CO_2 emission is 2240.88 Mt in 2002 and 3331.15 in 2007 Mt, which is lower than the results of China energy report 2008[18] and IEA[19]. This is because CO_2 emission is from related-fossil energy which calculated by the energy balance table, and the energy loss is not included in the production and transportation process in this paper.

Table 2 is the direct and indirect CO_2 emission intensity of different sector. In 2007, the five highest direct CO_2 emission intensities are found in Steel and iron products sector, Transportation & telecommunication sector, Non-metallic mineral products sector, Mining sector and Chemicals sector. Compared with other three years, we can find it did not exhibit the obvious change in the rank of these sectors, but the amount of CO_2 emission changed obviously. Generally, the direct CO_2 emission intensity of these sectors decrease from 1992 to 2007, expect for steel and iron products sector in 1997 (8.71 Mt/10000RMB) is higher than other three years. The lowest direct CO_2 emission intensity concentrated in Construction sector, Transport equipment and Agriculture, and they decreased from 1992 to 2007. The five highest indirect CO_2 emission intensities which is the emission induced by one unit of final demand of each sector, are found in Steel and iron products sector, Transportation & telecommunication sector, Non-metallic mineral products sector, Mining sector and Chemicals sector in 2007, and they decreased from 1997 to 2002. The most change occurred in Construction sector, Other manufacture, Transport equipment and Other industry which exhibited the high indirect CO_2 emission intensity compared with the low direct CO_2 emission intensity. This is because these sectors consumed a large number of intermediate inputs from other sectors. In addition, both direct and indirect CO_2 emission intensity

Table 2 Direct and indirect CO_2 emission intensity in different sectors

	1992 (t/10 thousand RMB)		1997 (t/10 thousand RMB)		2002 (t/10 thousand RMB)		2007 (t/10 thousand RMB)	
	Dir	Ind	Dir	Ind	Dir	Ind	Dir	Ind
Agriculture	0.39	1.65	0.33	1.48	0.31	1.05	0.32	0.89
Mining	1.12	2.39	1.23	2.67	1.28	2.26	1.02	2.38
Chemicals	3.55	8.36	2.25	5.64	1.10	2.88	0.70	2.06
Steel and iron products	6.77	12.23	8.71	14.77	3.68	6.52	3.37	6.10
Non-metallic Mineral Products	5.79	9.82	3.36	6.57	4.37	6.21	1.58	2.91
Transport Equipment	0.51	5.66	0.37	4.28	0.13	2.11	0.06	1.30
Electric Power, Gas and Water Production and Supply	0.34	1.92	1.61	3.40	0.60	1.66	0.22	1.09
Other manufacture	0.92	4.53	0.58	3.37	0.44	2.16	0.17	1.37
Construction	0.21	3.95	0.09	3.53	0.09	2.48	0.13	2.25
Transportation and telecommunication	2.65	6.04	2.49	4.03	1.53	2.59	1.47	2.13
Other industries	1.56	3.91	0.95	2.45	0.50	1.38	0.28	0.91
Average	2.16	5.50	2.00	4.74	1.28	2.85	0.85	2.13

average of all sectors decreased generally. It indicated energy saving and energy use efficiency obviously were changed in China.

4 CONCLUSIONS

This paper investigated the features and recent industrial structure changes and CO_2 emission in China associated with infrastructure development using input-output tables from 1992 to 2007.

We investigated the industrial structure changes. The results show the infrastructure industries, Electricity, steam, hot water production and supply sector and Transportation & telecommunication sector increased from 1992 to 2007, which arouse other industries, such as Construction sector, Steel and iron products sector and Transport equipment sector also increased at the sample period, Non-metallic mineral products increased up to 1997 and suddenly decreased in 2002. This may be due to the Chinese policy of construction waste reuse. Furthermore, according to the average annual increase rate of different stages, we can find Transport equipment and Non-metallic mineral products are growing industries, Electric power, gas, water production and supply sector is developing industry.

The researches of industrial repercussion effect show construction exhibited the largest backward linkage effect and it increased always from 1992 to 2007, the forward linkage effect of material sectors, such as steel and iron products, non-metallic products and chemicals increased. This indicated infrastructure construction drove the development of other material products sectors. So the policy of increasing infrastructure construction to

expand domestic demand is very important to economic stabilization and deal with the international economic situation, such as economic crisis, at the industrial development stage.

Lastly, we calculated CO_2 emission of each sector. The results indicated steel and iron products sector presented the most direct CO_2 emission especially in 2007. This is due to the infrastructure investment in China increased rapidly from 2002 to 2007 and a large amount of steel and iron products was consumed in this period. As to the indirect CO_2 emission, the other manufacture sector consumed intermediate products in production process, so it exhibited the most CO_2 emission which increased rapidly from 2002 to 2007. The CO_2 emission of construction induced by capital formation is far more than other sectors and it increased, especially from 2002 to 2007. As to the CO_2 emission intensity, steel and iron products have the highest direct and indirect CO_2 emission intensity. The indirect CO2 emission is far higher than direct CO2 emission for all sectors, thus, the related sectors must be also considered when improving energy efficient of one sector.

China's industry structure and CO_2 emission have recently been experiencing considerable change associated with the infrastructure development, especially from 2002 to 2007. The infrastructure construction can drive greatly the development of other industries, especially material industry, so we should improve the intermediate use efficiency and CO_2 emission intensity in the infrastructure construction.

In future, the factors affected CO_2 emission intensity of each sector should be analyzed. In addition, the industrial structure change of other country associated with infrastructure development, especially developed country should be studied and compared with which in China. The energy and resource consumption of infrastructure construction should be investigated in China.

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REFERENCES

1) NBS-National Bureau of Statistics of China: China Statistical Yearbook 1981–2004, *China Statistic Press, Beijing*, 1981-2004.
2) Yang, M. : China's energy efficiency target 2010, *Energy policy*, vol. 36, pp. 561-570, 2008.
3) NBS-National Bureau of Statistics of China: China Energy Statistical Yearbook 1981–2004, *China Statistic Press, Beijing*, 1981-2007.
4) Yan, Y. F., Yang, L. K. : China's foreign trade and climate change: A case study of CO_2 emissions, *Energy policy*, vol. 38, pp. 350-356, 2010.
5) Liu, A. Y. : Sources of Structural Change and Output Growth of China'sEconomy:1987-92: *Economics of Planning*, vol. 31, pp. 95-116, 1998.
6) Teng, J. : Input-output analysis of Chinese economy, *Kaisui press*, 2001.
7) Li, Q., Xue, T. D. : Analysis of economic sector in China – And Comparable prices input-output tables, *China Statistic Press, Beijing*, 1998.
8) Hu, Q. Y. : Interregional input-output analysis in China, *The 6th annual meeting collection of Chinese input-output association*, 2004.
9) Liu, X. B., Ishikawa, M. and Wang, C. : Analyses of CO_2 emissions embodied in Japan–China trade, *Energy policy*, vol. 38, pp. 1510-1518, 2010.
10) Lin, B. Q., Sun, C. W. : Evaluating carbon dioxide emissions in international trade of China, *Energy policy*, vol. 38, pp. 613-621, 2010.
11) Liu, H. T. and Gu, J. E. : Comprehensive evaluation of household indirect energy consumption and impacts of alternative energy policies in China by input-output analysis, *Energy policy*, vol. 37, pp. 3194-3204, 2009.
12) Hirschman, A. O. : The strategy of economic development, *Yale University Press, New Haven*, 1958.
13) IPCC. : 2006 IPCC Guidelines for National Greenhouse Gas Inventories. 2007.
14) http://www.researchandmarkets.com/reportinfo.asp?report_id=1207185
15) http://kjs.mep.gov.cn/hjbhbz/bzwb/wrfzjszc/200607/t20060725_91279.htm
16) Zhang, Z. : Research on the Economics and Management of the Chinese Construction Sector in the Transformation Period, *PhD dissertation, University of Harbin Building, Harbin*, 1996.
17) Xu, G. Q. : Decomposition model and empirical study of carbon emissions for China, 1995-2004, *China population, resource and environment*, vol. 16, 158-161.
18) Wei, Y. M. : China energy report (2008): CO_2 emission research, *Science press, Beijing*, 2008.
19) IEA (International energy agency): CO_2 emission from fuel combustion-Highlights, 2009.