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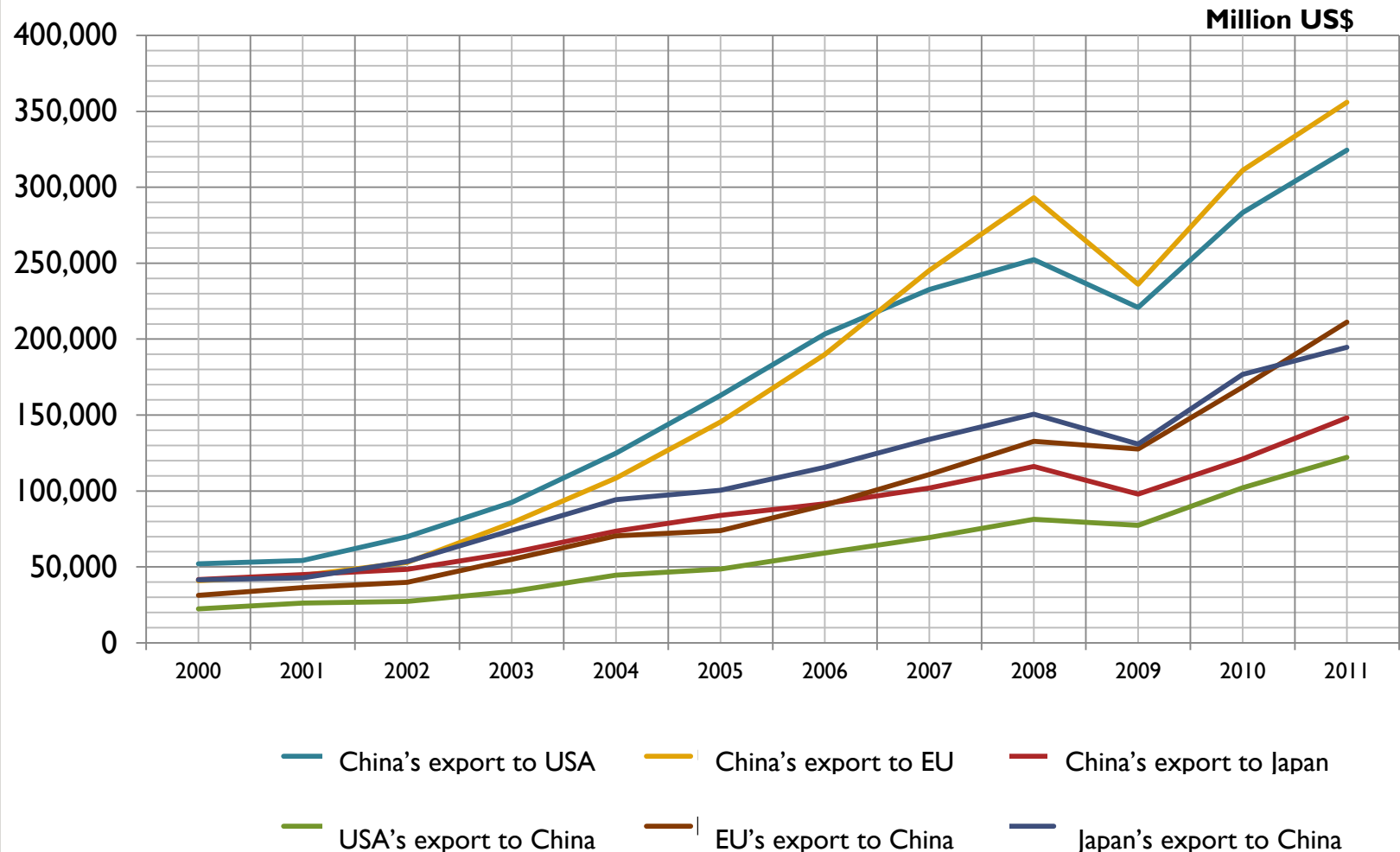
# **Chapter 19 – Measuring both production-based and consumption-based CO<sub>2</sub> emission of different countries based on multi-regional input-output model**

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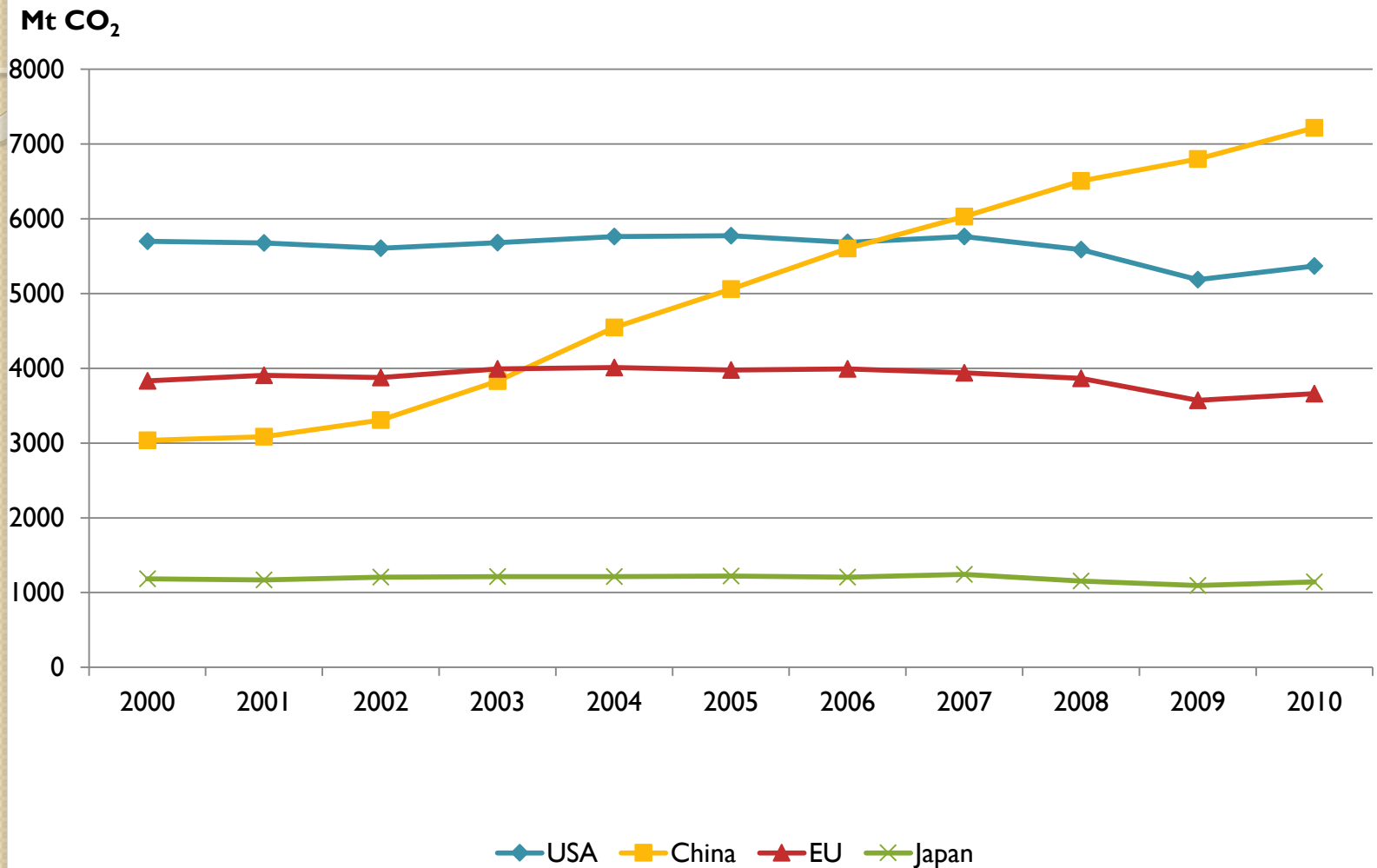
# **I. Background**

# I) Value of bilateral trade between China and Japan/USA/EU



( Source: GTAP8.0 database, 2012)

## 2) Carbon emission of China/Japan/USA/EU



(Source: IEA, *CO<sub>2</sub> emissions from fuel combustion highlights*, 2012)

### 3) Production-based emission and Consumption-based emission

- According to the production-based accounting principle, the CO<sub>2</sub> emissions from production for domestic consumption and exports are all included.
- This accounting method leads to the increasing of total CO<sub>2</sub> emissions of one country when its exports keeps increasing, whereas other highly import-dependent countries decrease its total CO<sub>2</sub> emissions by avoiding the domestic production.
- It is meaningful to take production-based and consumption-based CO<sub>2</sub> emissions into account at the same time.



## **2. Methodology**

# I) Aggregation by regions in GTAP 8

No.	Region	Countries (or regions) contained in this region
1	Mainland China	CHN
2	The United States	USA
3	European Union	AUT, BEL, CYP, CZE, DNK, EST, FIN, FRA, DEU, GRC, HUN, IRL, ITA, LVA, POL, LTU, LUX, MLT, NLD, PRT, SVK, ESP, SVN, SWE, GBR, BGR, ROU
4	Japan	JPN
5	The rest of world	HKG, TWN, XEA; AUS, NZL, XOC; KOR, KHM, IDN, LAO, MYS, PHL, SGP, THA, VNM, BGD, XSE, IND, PAK, LKA, XSA, KAZ, KGZ, XSU, IRN, ARM, AZE, GEO, TUR, XWS; CAN, MEX, XNA, BOL, BRA, CHL, ARG, URY, COL, ECU, PRY, PER, VEN, XSM, CRI, GTM, NIC, PAN, XCA, XCB; CHE, NOR, ALB, BLR, HRV, RUS, UKR, XEE, XEF, XER; EGY, MAR, TUN, XNF, NGA, SEN, XWF, XCF, XAC, ETH, MDG, MWI, MUS, MOZ, UGA, ZMB, ZWE, XEC, BWA, ZAF, XSC

## 2) Aggregation by industries in GTAP 8

No.	Aggregate Industry	Industries contained in this aggregate industry
1	Agriculture	pdr、 wht、 gro、 v_f、 osd、 c_b、 pfd、 ocr、 ctl、 oap、 rmk、 wol
2	Food processing	cmt、 omt、 vol、 mil、 pcr、 sgr、 ofd、 b_t
3	Energy extraction	coa、 oil、 gas
4	Other resources	frs、 fsh、 omn
5	Petrochemical	p_c、 crp
6	Metal smelting and products	i_s、 nfm、 fmp
7	Non-metallic Production	nmm



## 2) Aggregation by industries in GTAP 8

No.	Aggregate Industry	Industries contained in this aggregate industry
8	Textile and clothing	tex、 wap、 lea
9	Equipment manufacturing	mvh、 ele、 otn、 ome
10	Other manufacturing	ppp、 lum、 omf
11	Water, electricity and gas	ely、 gdt、 wtr
12	Construction	cns
13	Transportation	atp、 wtp、 otp
14	Services	trd、 cmn、 ofi、 isr、 obs、 ros、 osg、 dwe

### 3) Build the global multi-regional input-output table

		Intermediate inputs				Final consumption				Total Output	CO <sub>2</sub> Emission
		A	B	...	E	A	B	...	E		
Intermediate inputs	A	Z <sup>AA</sup>	Z <sup>AB</sup>	...	Z <sup>AE</sup>	Y <sup>AA</sup>	Y <sup>AB</sup>	...	Y <sup>AE</sup>	X <sup>A</sup>	C <sup>A</sup>
	B	Z <sup>BA</sup>	Z <sup>BB</sup>	...	Z <sup>BE</sup>	Y <sup>BA</sup>	Y <sup>BB</sup>	...	Y <sup>BE</sup>	X <sup>B</sup>	C <sup>B</sup>
	...	...	...	...	...	...	...	...	...	...	...
	E	Z <sup>EA</sup>	Z <sup>EB</sup>		Z <sup>EE</sup>	Y <sup>EA</sup>	Y <sup>EB</sup>		Y <sup>EE</sup>	X <sup>E</sup>	C <sup>E</sup>
Added values		...	...	...	...						
Total input		X <sup>A</sup>	X <sup>B</sup>	...	X <sup>E</sup>						

Assumption:

$$Z_{ij}^{sr} = Z_{ij}^{*r} \times \frac{e_i^{sr}}{m_i^r} \quad y_i^{sr} = y_i^{*r} \times \frac{e_i^{sr}}{m_i^r}$$

## 4) Calculate the production-based and consumption-based CO<sub>2</sub> emissions

$$\begin{pmatrix} X^A \\ X^B \\ \vdots \\ X^E \end{pmatrix} = \begin{pmatrix} A^{AA} & A^{AB} & \dots & A^{AE} \\ A^{BA} & A^{BB} & \dots & A^{BE} \\ \vdots & \vdots & \ddots & \vdots \\ A^{EA} & A^{EB} & \dots & A^{EE} \end{pmatrix} \begin{pmatrix} X^A \\ X^B \\ \vdots \\ X^E \end{pmatrix} + \begin{pmatrix} \sum_{k=A}^E Y^{Ak} \\ \sum_{k=A}^E Y^{Bk} \\ \vdots \\ \sum_{k=A}^E Y^{Ek} \end{pmatrix}$$

$$p^r = (Y^{rA} \quad Y^{rB} \quad \dots \quad Y^{rE})$$

Production-based CO<sub>2</sub> emissions:  $C_p^r = E(I - A)^{-1} \hat{p}^r$

$$d^r = (Y^{Ar} \quad Y^{Br} \quad \dots \quad Y^{Er})^T$$

Consumption-based CO<sub>2</sub> emissions:  $C_d^r = E(I - A)^{-1} \hat{d}^r$



## **3. Results**

# I ) Production-based CO<sub>2</sub> emissions and consumption-based CO<sub>2</sub> emissions

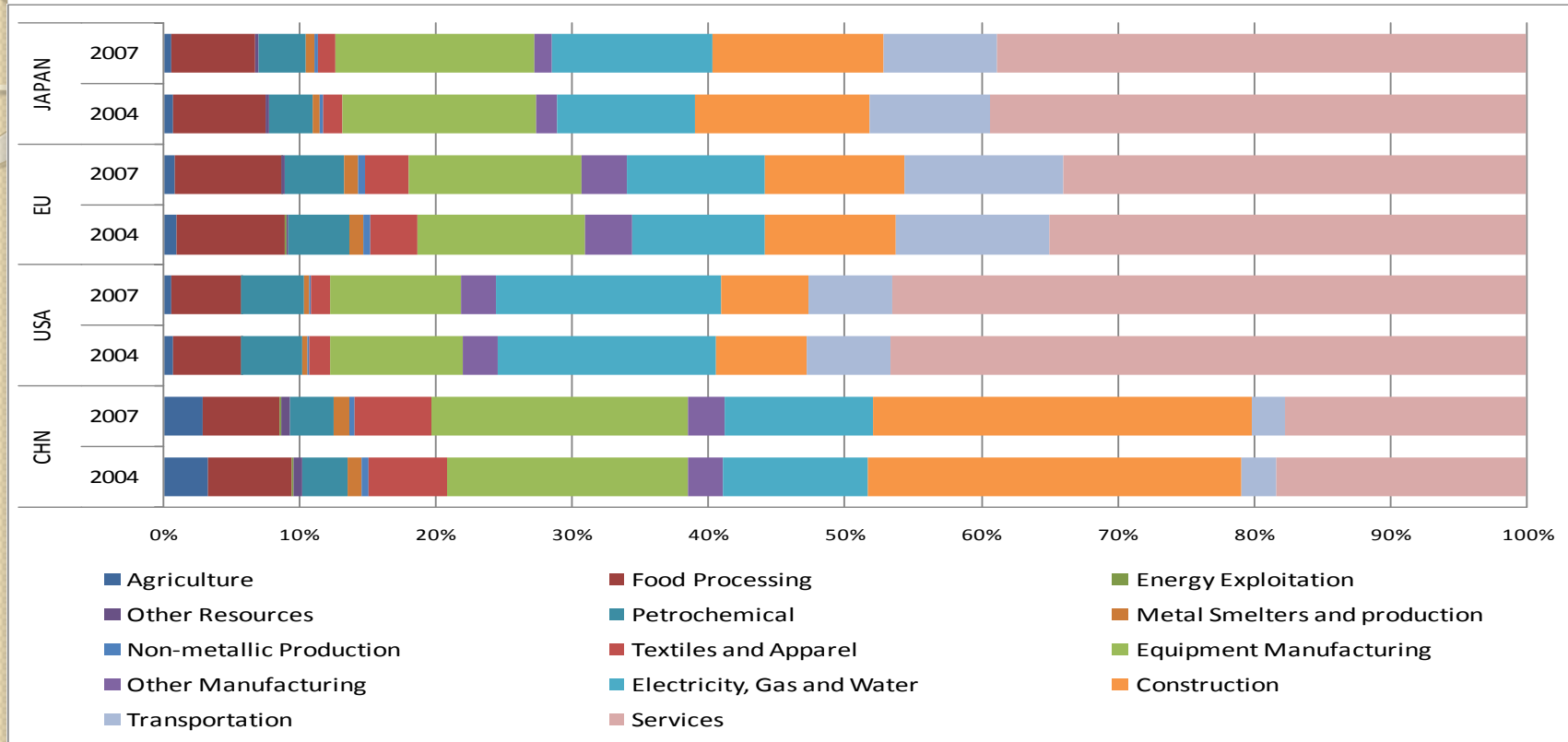
	2004			2007		
	Production-based (Mt CO <sub>2</sub> )	Consumption-based (Mt CO <sub>2</sub> )	Production-based V.S. consumption-based	Production-based (Mt CO <sub>2</sub> )	Consumption-based (Mt CO <sub>2</sub> )	Production-based V.S. consumption-based
China	3704.19	3205.94	15.54%	4688.89	4045.40	15.91%
USA	5933.18	6285.96	-5.61%	5964.01	6272.62	-4.92%
EU	4637.76	4919.42	-5.73%	4719.48	4975.91	-5.15%
JAPAN	1239.03	1348.87	-8.14%	1228.99	1283.61	-4.26%

There are often some differences in measuring a country's carbon emission through production-based method and consumption-based method, especially for those typical export-oriented economies such as China, Japan, EU and the United States.

## 2) Production-based CO<sub>2</sub> emissions of each industry

Mt CO <sub>2</sub>	CHN		USA		EU		JAPAN	
	2004	2007	2004	2007	2004	2007	2004	2007
Agriculture	118.80	132.90	39.47	34.22	43.72	39.04	8.29	6.99
Food Processing	228.97	266.97	295.10	301.80	371.76	368.16	84.61	75.79
Energy Exploitation	5.53	4.68	0.04	0.04	0.54	0.44	0.00	0.00
Other Resources	23.86	27.98	4.06	4.11	8.37	9.37	2.71	2.74
Petrochemical	122.90	153.43	266.09	273.13	207.95	208.00	39.61	43.07
Metal Smelters and production	38.18	54.63	21.08	21.52	44.81	47.41	6.73	7.88
Non-metallic Production	16.72	19.18	7.61	8.79	23.82	24.10	2.82	2.94
Textiles and Apparel	213.62	259.76	91.13	87.50	161.45	154.77	18.00	15.30
Equipment Manufacturing	656.66	882.22	575.46	572.33	570.31	596.93	175.89	178.99
Other Manufacturing	95.70	126.40	157.24	152.03	159.81	159.18	18.61	16.50
Electricity, Gas and Water	392.70	512.67	949.75	981.46	455.92	476.62	125.73	144.30
Construction	1017.31	1301.38	389.33	383.99	443.60	483.26	159.31	154.56
Transportation	91.35	116.40	367.57	370.81	524.65	550.03	108.60	102.95
Services	681.90	830.28	2769.23	2772.27	1621.02	1602.17	488.14	476.98

### 3) Industrial distribution of production-based CO<sub>2</sub> emission



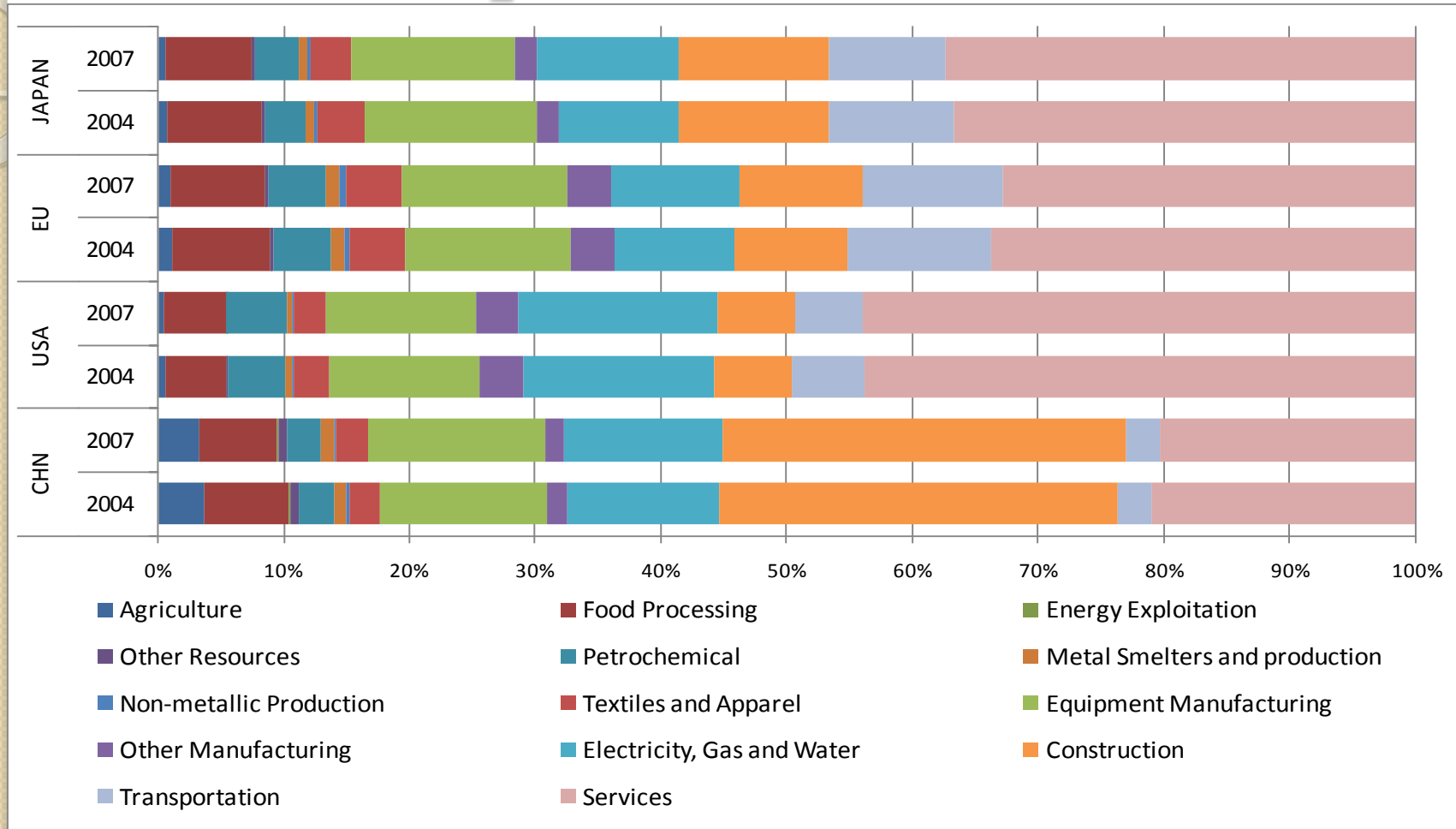
- ❑ The CO<sub>2</sub> emission of Equipment Manufacturing industry in China is higher than that of United States and EU;
- ❑ The Equipment Manufacturing industry is a main carbon emission source in China;
- ❑ The Electricity industry is also a main carbon emission source in all countries;

# 4) Consumption-based CO<sub>2</sub> emissions of each industry

Mt CO <sub>2</sub>	CHN		USA		EU		JAPAN	
	2004	2007	2004	2007	2004	2007	2004	2007
Agriculture	116.42	130.43	36.93	31.34	54.71	46.80	10.05	8.03
Food Processing	215.20	252.82	305.16	308.08	382.63	376.77	100.99	87.72
Energy Exploitation	5.37	4.63	0.00	0.00	3.27	3.03	0.37	0.60
Other Resources	23.55	27.84	4.12	4.19	10.96	11.55	3.58	3.13
Petrochemical	88.54	110.08	294.61	298.66	227.15	229.63	43.07	44.47
Metal Smelters and production	28.82	38.97	27.49	25.82	48.54	51.50	9.32	9.27
Non-metallic Production	8.98	9.47	12.93	13.22	23.63	24.35	3.65	3.45
Textiles and Apparel	80.41	99.24	172.48	157.51	219.51	219.43	50.65	39.74
Equipment Manufacturing	424.93	574.08	750.86	744.12	643.27	655.07	184.63	167.75
Other Manufacturing	51.55	60.64	223.15	217.82	171.75	174.20	24.04	21.92
Electricity, Gas and Water	388.35	507.13	955.32	991.43	467.78	506.89	127.45	144.97
Construction	1014.71	1297.79	389.13	383.12	446.74	486.65	162.20	153.55
Transportation	84.40	109.78	354.97	341.23	560.59	557.05	134.20	119.54
Services	674.71	822.51	2758.78	2756.08	1658.9	1633.0	494.67	479.48



# 5) Industrial distribution of consumption-based CO<sub>2</sub> emission

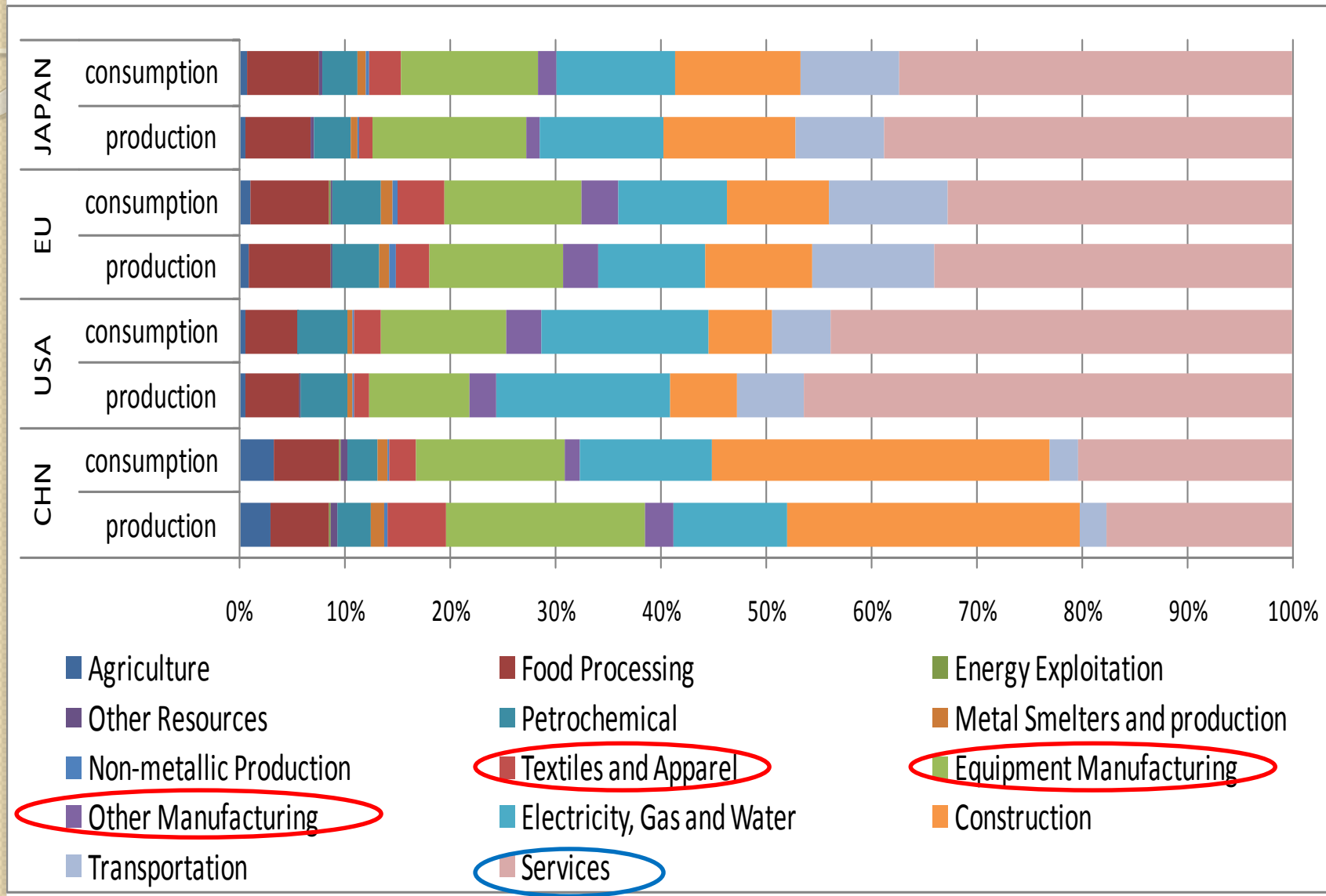


- When calculating the consumption-based CO<sub>2</sub> emission, the emission of Equipment Manufacturing in China becomes less than that of the United States and EU.

## 6) Comparison of production-based and consumption-based CO<sub>2</sub> emissions of each industry in the year of 2007

Mt CO <sub>2</sub>	CHN		USA		EU		JAPAN	
	Prod.-based	Cons.-based	Prod.-based	Cons.-based	Prod.-based	Cons.-based	Prod.-based	Cons.-based
Agriculture	132.90	130.43	34.22	31.34	39.04	46.80	6.99	8.03
Food Processing	266.97	252.82	301.80	308.08	368.16	376.77	75.79	87.72
Energy Exploitation	4.68	4.63	0.04	0.00	0.44	3.03	0.00	0.60
Other Resources	27.98	27.84	4.11	4.19	9.37	11.55	2.74	3.13
Petrochemical	153.43	110.08	273.13	298.66	208.00	229.63	43.07	44.47
Metal Smelters and production	54.63	38.97	21.52	25.82	47.41	51.50	7.88	9.27
Non-metallic Production	19.18	9.47	8.79	13.22	24.10	24.35	2.94	3.45
Textiles and Apparel	259.76	99.24	87.50	157.51	154.77	219.43	15.30	39.74
Equipment Manufacturing	882.22	574.08	572.33	744.12	596.93	655.07	178.99	167.75
Other Manufacturing	126.40	60.64	152.03	217.82	159.18	174.20	16.50	21.92
Electricity, Gas and Water	512.67	507.13	981.46	991.43	476.62	506.89	144.30	144.97
Construction	1301.38	1297.79	383.99	383.12	483.26	486.65	154.56	153.55
Transportation	116.40	109.78	370.81	341.23	550.03	557.05	102.95	119.54
Services	830.28	822.51	2772.27	2756.08	1602.17	1633.0	476.98	479.48

# 7) Comparison of production-based and consumption-based CO<sub>2</sub> emissions of each industry in the year of 2007



## 8) Comparison of the carbon emission embodied in international trade of China, the United States, Europe and Japan

Mt CO <sub>2</sub>	2004			2007		
	CO <sub>2</sub> emission embodied in export (A)	CO <sub>2</sub> emission embodied in import (B)	Net export of embodied carbon (A-B)	CO <sub>2</sub> emission embodied in export (A)	CO <sub>2</sub> emission embodied in import (B)	Net export of embodied carbon (A-B)
China	564.19	65.94	498.26	721.23	77.74	643.49
USA	270.81	623.59	-352.78	276.97	585.58	-308.61
EU	281.03	562.70	-281.67	308.48	564.91	-256.43
Japan	87.94	197.78	-109.84	98.76	153.38	-54.62


## 9) Comparison of between imported and exported embodied CO<sub>2</sub> emission in the bilateral trade of China, the United States, Europe and


Mt CO <sub>2</sub>	2004			2007		
	CO <sub>2</sub> emission embodied in export (A)	CO <sub>2</sub> emission embodied in import (B)	Net export of embodied carbon (A-B)	CO <sub>2</sub> emission embodied in export (A)	CO <sub>2</sub> emission embodied in import (B)	Net export of embodied carbon (A-B)
Sino-USA	172.38	5.41	166.96	203.21	7.15	196.06
Sino-EU	125.34	7.25	118.09	160.26	9.11	151.15
Sino-Japan	81.71	6.67	75.04	69.01	8.33	60.67

- ❑ In the year of 2004 and 2007, Chinese total amount of embodied CO<sub>2</sub> emission that exported to the USA, EU, and Japan accounts for more than 9% of domestic carbon emission, reaching 60% of exported embodied CO<sub>2</sub> emission over the same period.




## **4. Conclusions and discussions**

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- The results of each country's production-based CO<sub>2</sub> emissions and consumption-based CO<sub>2</sub> emissions by using the global multi-regional input-output table varied significantly, especially for those export-oriented economies such as China, the United States, EU, and Japan.
  - The production-based CO<sub>2</sub> emission of China is 15% higher than the consumption-based CO<sub>2</sub> emission in 2004 and 2007, whereas the production-based CO<sub>2</sub> emission of the United States, EU, and Japan is about 5% less than the consumption-based emission.
  - The production-based CO<sub>2</sub> emissions of diverse industries in China are all more or less higher than the consumption-based CO<sub>2</sub> emission, but the situations in the United States, EU, and Japan are contrary to China.

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- In the international trade, China is a typical net exporter of embodied carbon. The amount of exported embodied carbon has accounted more than 15% of the national production-based CO<sub>2</sub> emissions during 2004 and 2007, whereas this proportion of imported embodied carbon is only 2% or so, and the amount of net export of embodied carbon shows a trend of further expansion.
  - The United States, EU, and Japan are all net importers of embodied carbon. The amount of imported embodied carbon in these three countries has accounted about 10% of their national production-based CO<sub>2</sub> emission in 2004 and 2007, which is much higher than their exported embodied carbon.



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- As the main trading partner of China, the United States, EU, and Japan are also main beneficiaries of Chinese exported embodied carbon. From the point of view of bilateral trade, the CO<sub>2</sub> emission embodied in the export of China to the United States, EU, and Japan can account about 60% of the total exported embodied carbon of China.
  - From 2004 to 2007, the scale of CO<sub>2</sub> emission embodied in the export from China to the USA and EU increased significantly.
  - In spite of the decrease in the exported embodied carbon from China to Japan, China is still a net exporter of embodied carbon in the bilateral trade between China and Japan.



**Thanks!**