The Environmental Pains and Economic Gains of Outsourcing to China

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Abstract: When taking into account the dominant share of processing exports in overall exports volume, for instance 51% in 2007 (55% in 2002), it is crucial to address greenhouse gas emission issue generated in exports by processing type. Contrary to most previous studies, it is found that processing exports have lower pollution coefficient, which implies Chinese exports contribute relatively low to climate change (e.g. CO2 emissions generated by processing exports account for 2%, and non-processing exports contribute 10% of total emissions). Following these findings, different from ordinary exports, processing exports are especially coherent with "emissions avoided by imports" fashion; in turn, the pollution balance turns out to be much smaller than ordinary ones.

On the other hand, a lot of work has been done currently, qualitatively or quantitatively, on the value added or economic benefits for China generated by processing exports, and most people argue that although the volume of processing export are quite large, its economic benefits are relatively small (to give an example, the total domestic value added generated by 1 unit processing exports is about 0.287; however, the benefit gains from 1 unit non-processing exports is roughly 0.633).

Needless to say, processing trade will be a most important part in China's trade in a rather long time in the future (though probably with a gradual diminishing share), we argue that processing trade to China is an "environmentally-friendly" export type (compared with similar products in ordinary trade) since it has a much shorter domestic production chain. Meanwhile it could be viewed as climate change (less) harmless behavior, though at the cost of value added, or gains and pains game. Furthermore, it

would be highlighted that one of the most important things for China is how to adjust the products share in processing trade, in order to get a trade-off between climate change control and economic benefits.

Keywords: processing exports, climate change, value added, pains and gains
JEL Codes: C67; Q56; O47; F14

Acknowledgements: The authors are very grateful to Glen Peters for providing his spreadsheets with emission data and to Dr. Kunfu ZHU for providing the dataset with the detailed version of the tripartite input-output table. This work was supported by National Natural Science Foundation of China [70221001, 70871108, 70810107020]; and the Knowledge Innovation Project of the Chinese Academy of Sciences.

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1. Introduction

Globalization has many facets, one of them being the upsurge of trade in emissions. It is well known that some countries that have ratified the Kyoto protocol transfer some of their polluting production activities to so-called pollution havens with regulations that are more lax. As a consequence, these countries may meet the targets whereas they are responsible for an increase in worldwide pollution. This has raised the discussion whether to focus on the producer's responsibility (i.e. all emissions generated by the production activities of a country) or the consumer's responsibility (i.e. all emissions that are necessary worldwide to satisfy the needs of the 'consumers' of a country, where 'consumption' includes private and government consumption and investments), see e.g. Gallego and Lenzen (2005), Rodrigues *et al*. (2006), and Lenzen and Murray (2007) for recent contributions. The difference between the two responsibilities is given by the trade in emissions (Serrano and Dietzenbacher, 2008). This issue has also reached the policy debate, as witnessed by the question whether China can be held responsible for all of its emissions. Weber *et al*. (2008), for example, have estimated that roughly one third of China's greenhouse gas (GHG) emissions were due to exports and thus 'on behalf of foreign consumers'.

Another facet of globalization is the increase in outsourcing (and offshoring) production activities to other countries. Due to low wages, in particular developing countries have been targeted for outsourcing in order to cut the production costs. This implies a huge amount of processing trade. In the case of processing trade, a large share (or even all) of the raw and auxiliary materials, parts and components, accessories, and packaging materials are imported from abroad free of duty, and the finished products are re-exported again after they have been processed or assembled by enterprises. For example, for China we find (see Figure 1) that these processing exports have accounted for more than 50% of its annual total exports in the period 1995-2007 (although it is expected to decline slowly because outsourcing to China will become less attractive due to raising wages).

Insert Figure 1

Our first major finding is that Chinese emissions necessary for the country's exports are overestimated by more than 60%, if the distinction between processing and non-processing exports is *not* taken into account. For our analysis we use an input-output (IO) framework. In particular for ascribing (i.e. measuring) certain effects (e.g. emissions) to actions that have taken place (e.g. exports or private consumption), the IO framework is appropriate. Overviews focusing on the use of IO to analyze environmental issues are included in Forssell (1998), Forssell and Polenske (1998), Suh and Kagawa (2005), Turner *et al*. (2007), and Wiedmann *et al*. (2007).

Recently, a special, tripartite IO table has been estimated for China (see Lau *et al*., 2006, 2007, for details of the table construction). Lau *et al*. (2006, 2007) report that the total domestic value added generated by 1000 Renminbi (Rmb) of processing exports and non-processing exports are 287 Rmb and 633 Rmb, respectively. Our second major finding is that processing exports have a substantially lower cost-benefit ratio than non-processing exports.

The remainder of the paper is structured as follows. Section 2 introduces the methodology and deals with data issues; Section 3 discusses the 'pains' and the 'gains', and compares their ratio for the different types of exports. Section 4 concludes and Section 5 discusses and provides some policy recommendations.

2. Methodology

Our starting point is a unique, tripartite IO table for China in 2002, the structure of which is outlined in Figure 2[1].

Insert Figure 2

The framework is very similar to that of an interregional IO (IRIO) table with three regions (see Miller and Blair, 1985). The structure of ordinary IO table is outlined

[1] See Lau *et al*. (2006, 2007), Yang and Pei (2007) or Yang *et al*. (2009) for a detailed discussion and applications.

in Figure 3.

Insert Figure 3

The matrices of input coefficients are obtained as follows. For the ‘ordinary’ IO table we have $\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1}$ and its element $a_{ij} = z_{ij} / x_j$ gives the input of good i per unit of output of industry j. For the tripartite IO table we have,

$$\overline{\mathbf{A}} = \begin{bmatrix} \mathbf{A}^{DD} & \mathbf{A}^{DP} & \mathbf{A}^{DN} \\ 0 & 0 & 0 \\ \mathbf{A}^{ND} & \mathbf{A}^{NP} & \mathbf{A}^{NN} \end{bmatrix} \tag{1}$$

For the ‘ordinary’ IO table in Figure 3, we will use

$$\mathbf{g}^{(\mathbf{f})} = \hat{\boldsymbol{\mu}}\mathbf{L}\mathbf{f} \tag{2a}$$

$$\mathbf{g}^{(\mathbf{e})} = \hat{\boldsymbol{\mu}}\mathbf{L}\mathbf{e} \tag{2b}$$

In the same fashion, we find for the tripartite IO table in Figure 2 that the Leontief inverse is given by

$$\overline{\mathbf{L}} = (\mathbf{I} - \overline{\mathbf{A}})^{-1} = \begin{bmatrix} \mathbf{L}^{DD} & \mathbf{L}^{DP} & \mathbf{L}^{DN} \\ 0 & \mathbf{I} & 0 \\ \mathbf{L}^{ND} & \mathbf{L}^{NP} & \mathbf{L}^{NN} \end{bmatrix} \tag{3}$$

The direct emission coefficients are given by $(\boldsymbol{\mu}^D)' = (\mathbf{r}^D)'(\hat{\mathbf{x}}^D)^{-1}$ for type D producers (and similar expressions for type P and N producers). The emissions that are necessary for each of the four categories of final use in Figure 2, are given by

$$\mathbf{g}^{(\mathbf{f}^D)} = (\hat{\boldsymbol{\mu}}^D\mathbf{L}^{DD} + \hat{\boldsymbol{\mu}}^N\mathbf{L}^{ND})\mathbf{f}^D \tag{4a}$$

$$\mathbf{g}^{(\mathbf{f}^N)} = (\hat{\boldsymbol{\mu}}^D \mathbf{L}^{DN} + \hat{\boldsymbol{\mu}}^N \mathbf{L}^{NN})\mathbf{f}^N \tag{4b}$$

$$\mathbf{g}^{(\mathbf{e}^P)} = (\hat{\boldsymbol{\mu}}^D \mathbf{L}^{DP} + \hat{\boldsymbol{\mu}}^P + \hat{\boldsymbol{\mu}}^N \mathbf{L}^{NP})\mathbf{e}^P \tag{4c}$$

$$\mathbf{g}^{(\mathbf{e}^N)} = (\hat{\boldsymbol{\mu}}^D \mathbf{L}^{DN} + \hat{\boldsymbol{\mu}}^N \mathbf{L}^{NN})\mathbf{e}^N \tag{4d}$$

where, for example, the *i*th element of the column vector in (4a) indicates the emissions by all industries *i* (i.e. in class *D*, *P* and *N*) that are necessary for satisfying the domestic final demands for goods produced in class *D*.

The first set assumes that the emission coefficient for industry *i* is the same in each class. That is, we have used $\boldsymbol{\mu}^D = \boldsymbol{\mu}^P = \boldsymbol{\mu}^N = \boldsymbol{\mu}$.

For the second set of calculations, we have estimated separate coefficients for each of the three classes. In the overall case (corresponding to Figure 3) we have that the domestic intermediate inputs of industry *i* are given by the *i*th element of the row vector $\boldsymbol{\rho}' = \mathbf{s}'\mathbf{A}$, where $\mathbf{s}$ indicates the summation vector consisting of ones. The domestic intermediate inputs in each of the three classes is given by $(\boldsymbol{\rho}^D)' = \mathbf{s}'(\mathbf{A}^{DD} + \mathbf{A}^{ND})$, $(\boldsymbol{\rho}^P)' = \mathbf{s}'(\mathbf{A}^{DP} + \mathbf{A}^{NP})$ and $(\boldsymbol{\rho}^N)' = \mathbf{s}'(\mathbf{A}^{DN} + \mathbf{A}^{NN})$. The estimated emission coefficients are then obtained as

$$\mu_i^D = \frac{\rho_i^D}{\rho_i}\mu_i\,,\ \mu_i^P = \frac{\rho_i^P}{\rho_i}\mu_i\,,\text{ and }\ \mu_i^N = \frac{\rho_i^N}{\rho_i}\mu_i \tag{5}$$

Note that these class-specific emission coefficients still yield the correct total emissions in each industry. That is,

$$\mu_i^D x_i^D + \mu_i^P x_i^P + \mu_i^N x_i^N = \mu_i x_i = r_i \tag{6}$$

Finally, a similar set of calculations has been carried out for the value added in each industry.

3. The Results for China in 2002

3.1. The Pains and Gains

Table 1 presents the results at the aggregate (national) level, i.e. the emissions in each industry have been summed over the industries.

Insert Table 1

3.2. The Pains versus the Gains

The cost-benefit ratios are calculated in this section. From equation (4a), we may derive that the ith element of the row vector $(\boldsymbol{\mu}^D)'\mathbf{L}^{DD} + (\boldsymbol{\mu}^N)'\mathbf{L}^{ND}$ gives the total amount of emissions per unit of final demand for good i produced in class D (for domestic use only). This is an environmental 'pain' or cost. In the same fashion, the ith element of the row vector $(\boldsymbol{\upsilon}^D)'\mathbf{L}^{DD} + (\boldsymbol{\upsilon}^N)'\mathbf{L}^{ND}$ gives the corresponding amount of value added, i.e. the economic 'gain' or benefit. Their ratio

$$\xi_i^D = \frac{[(\boldsymbol{\mu}^D)'\mathbf{L}^{DD} + (\boldsymbol{\mu}^N)'\mathbf{L}^{ND}]_i}{[(\boldsymbol{\upsilon}^D)'\mathbf{L}^{DD} + (\boldsymbol{\upsilon}^N)'\mathbf{L}^{ND}]_i}$$

expresses how much CO_2 is emitted per unit of value added, both corresponding to the final demand for good i produced in class D (i.e. f_i^D).

For the final demands for good i in the other classes (i.e. e_i^P in class P, and f_i^N or e_i^N in class N), we have the following cost-benefit ratios.

$$\xi_i^P = \frac{[(\boldsymbol{\mu}^D)'\mathbf{L}^{DP} + (\boldsymbol{\mu}^P)' + (\boldsymbol{\mu}^N)'\mathbf{L}^{NP}]_i}{[(\boldsymbol{\upsilon}^D)'\mathbf{L}^{DP} + (\boldsymbol{\upsilon}^P)' + (\boldsymbol{\upsilon}^N)'\mathbf{L}^{NP}]_i} \quad \text{and} \quad \xi_i^N = \frac{[(\boldsymbol{\mu}^D)'\mathbf{L}^{DN} + (\boldsymbol{\mu}^N)'\mathbf{L}^{NN}]_i}{[(\boldsymbol{\upsilon}^D)'\mathbf{L}^{DN} + (\boldsymbol{\upsilon}^N)'\mathbf{L}^{NN}]_i}$$

where $[...]_i$ indicates the ith element of the vector between brackets.

From the results in Table 1 we can calculate straightforwardly that the average for the processing exports vector $\mathbf{e}^P$ is 0.19, whereas it is 0.29 for the vector of non-processing exports $\mathbf{e}^N$. It should be noted, however, that this average uses value added shares as weights. That is, for the non-processing exports, for example,

$$0.29 = \frac{358.19}{1245.13} = \Sigma_i \xi_i^N w_i^N \quad \text{with} \quad w_i^N = \frac{[(\upsilon^D)' L^{DN} + (\upsilon^N)' L^{NN}]_i e_i^N}{\Sigma_i [(\upsilon^D)' L^{DN} + (\upsilon^N)' L^{NN}]_i e_i^N} \tag{7}$$

where the denominator in w_i^N indicates the value added generated by final demand e_i^N as a share of the value added generated by all non-processing exports.

Instead of using value added shares as weights, we may also take the final demand components as the basis of the weights. For example for the processing exports this yields

$$\Sigma_i \xi_i^P w_i^P \quad \text{with} \quad w_i^P = \frac{e_i^P}{\Sigma_i e_i^P} \tag{8}$$

Alternatively, the harmonic mean is based on the weighted average of the reciprocals. That is,

$$\frac{1}{\Sigma_i (1/\xi_i^P) w_i^P} \quad \text{with} \quad w_i^P = \frac{e_i^P}{\Sigma_i e_i^P} \tag{9}$$

The results are given in Table 2.

4. Concluding Remarks

Processing exports are major part of China's exports which emit less. While it is relatively low in comparison with non-processing ones for generating value added. However, if we take a closer look at Table 2 of the ratios, we may get clear picture of trade-off. On average promoting processing exports is still one good option to some extent currently.

This paper also shows an example to estimate the export's contribution both to climate change and economic growth precisely. The methodology applies to those developing countries performing considerable share of processing trade.

References Omitted.

Figure 1. Historical trend of processing exports share (% of total exports): 1981-2007

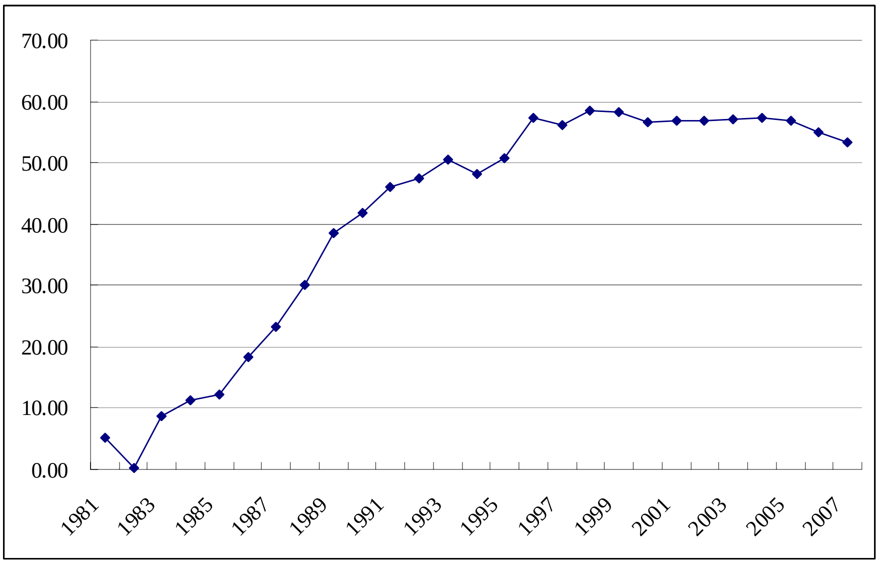

Figure 2. The structure of China's tripartite input-output table, including processing trade

	Intermediate use			Final use		
	D	*P*	*N*	*DFD*	*EXP*	*TOT*
D	$\mathbf{Z}^{DD}$	$\mathbf{Z}^{DP}$	$\mathbf{Z}^{DN}$	$\mathbf{f}^{D}$	0	$\mathbf{x}^{D}$
P	0	0	0	0	$\mathbf{e}^{P}$	$\mathbf{x}^{P}$
N	$\mathbf{Z}^{ND}$	$\mathbf{Z}^{NP}$	$\mathbf{Z}^{NN}$	$\mathbf{f}^{N}$	$\mathbf{e}^{N}$	$\mathbf{x}^{N}$
IMP	$\mathbf{M}^{D}$	$\mathbf{M}^{P}$	$\mathbf{M}^{N}$	$\mathbf{f}^{M}$	0	$\mathbf{x}^{M}$
VA	$(\mathbf{v}^{D})'$	$(\mathbf{v}^{P})'$	$(\mathbf{v}^{N})'$			
TOT	$(\mathbf{x}^{D})'$	$(\mathbf{x}^{P})'$	$(\mathbf{x}^{N})'$			

Notes: *D* = industries producing for domestic use; *P* = industries producing processing exports; *N* = industries producing non-processing exports and other production of foreign-invested enterprises; *DFD* = domestic final demand; *EXP* = exports; *TOT* = gross industry outputs (and total imports in the column *TOT*); *IMP* = imports; and *VA* = value added.

Figure 3. The structure of China's 'ordinary' national input-output table

	Intermediate use	Final use		
		DFD	*EXP*	*TOT*
	$\mathbf{Z}$	$\mathbf{f}$	$\mathbf{e}$	$\mathbf{x}$
IMP	$\mathbf{M}$	$\mathbf{f}^{M}$	0	$\mathbf{x}^{M}$
VA	$\mathbf{v}'$			
TOT	$\mathbf{x}'$			

Table 1. Overview of results at the aggregate level, emissions and values added per final demand category

	Tripartite IO table				Ordinary IO table	
	Domestic		Exports		Domestic	Exports
	D	*N*	*P*	*N*		
	(4a)	(4b)	(4c)	(4d)	(2a)	(2b)
CO_2						
separate coeffs	2512.84	463.98	71.30	358.19	2716.01	690.30
(%)	(73.77)	(13.62)	(2.09)	(10.52)	(79.73)	(20.27)
identical coeffs	2498.31	443.85	96.07	368.09		
(%)	(73.34)	(13.03)	(2.82)	(10.81)		
SO_2						
separate coeffs	19289.24	3818.54	481.05	2650.48	20823.31	5415.91
(%)	(73.51)	(14.55)	(1.83)	(10.10)	(79.36)	(20.64)
identical coeffs	19188.60	3648.37	657.76	2744.58		
(%)	(73.13)	(13.90)	(2.51)	(10.46)		
NO_x						
separate coeffs	9013.47	2023.52	308.37	1484.40	10175.49	2654.23
(%)	(70.25)	(15.77)	(2.40)	(11.57)	(79.31)	(20.69)
identical coeffs	9122.67	1873.64	376.66	1456.79		
(%)	(71.11)	(14.60)	(2.94)	(11.35)		
Value added						
nominal	9847.47	719.59	373.70	1245.13	9837.54	2348.35
(%)	(80.81)	(5.90)	(3.07)	(10.22)	(80.73)	(19.27)

Notes: CO_2 emissions are in Mt, SO_2 and NO_x emissions are in kt, and values added are in billion Rmb

Table 2. Cost-benefit ratios of final demands per class of production

	D	*P*	*N*	
Averages	Domestic	Exports	Domestic	Exports
Value added shares, equation (7)	0.26	0.19	0.64	0.29
Final demand shares, equation (8)	0.26	0.21	0.61	0.32
Harmonic mean, equation (9)	0.20	0.18	0.27	0.24