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Energy Consumption Coefficient Comparison of Outsourcing to China: An Input-output Analysis

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Abstract: China is a major destination of international outsourcing. Processing trade accounts for around 50% of China's total trade volume. Comparing with "ordinary" export, processing export generates much lower value added for China, since its domestic economic activity much less than other exports type, its intermediate use structure is quite different from other products. On the other hand, processing export is expected to have lower energy consumption coefficient, especially when considering the chain effect across sectors, i.e., total energy consumption coefficient, which implies that though processing exports is economically inefficient but may be 'friendly' in both energy saving and environmental pollution within China. In this paper, we employed a non-competitive input-output model capturing China's processing trade, of which China's domestic production is divided into three parts: production for domestic use only, processing exports, non-processing exports and other production of FIEs, to conduct comparative analysis on energy consumption of different production activities over time. Due to data limits, we proposed two kinds of treatment to estimate the direct energy consumption coefficients by different production type. Since most of the intermediate material of processing exports is imported, processing trade is less intensive as a whole in using China's energy.

Keywords: Processing export, Input-output tables, Energy consumption coefficient

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1. Introduction

China's foreign trade has developed very rapidly since the reforms and the country's opening-up to the outside world, in particular after its entry to the WTO in 2001. The ratio between China's foreign trade volume and its GDP, rose from 38.7% in 1995 to 69.1% in 2006. Yet, this huge trade dependence is somewhat misleading in the sense that the contribution of Chinese exports in generating GDP is relatively modest from our previous research. The most important reason is that processing trade accounts for about 50% of China's foreign trade, of which processing exports (which constituted 50.7% and 47.2% of total exports in 2007 and 2008) induce much less domestic economic activity than ordinary (non-processing) exports do[2]. Lau *et al.* (2006) estimated for 2002 that the value added generated by one million RMB of processing exports was only 38% of the value added generated by one million RMB of non-processing exports. Similar findings have been reported in Koopman *et al.* (2008).

At the end of 2007, the Chinese government made some policy adjustment on processing trade in an effort to drive the transformation and upgrade of processing trade. The adjustments include restrictions on certain products of several labor-intensive or energy-intensive industries including textile, chemicals, plastic material and furniture, and removal of decline of tax rebates for certain export products. From the definition and structure of processing export, we could see that the domestic economic activity of processing export is much less than other exports type, its intermediate use structure is quite different from other products, consequently processing export is expected to have lower energy consumption coefficient, especially when considering the chain effect across sectors, that is, total energy consumption coefficient, which implies that though processing exports is

[2] Processing trade refers to the business activity of importing all or part of the raw and auxiliary materials, parts and components, accessories, and packaging materials from abroad free of duty, and re-exporting the finished products after processing or assembly by enterprises within Mainland China. Imported goods under the item of processing trade (usually called processing import) can only be used to produce exported goods in which case known as processing exports, but not allowed for other purposes, otherwise, it would be considered to violate the regulations.

economically inefficient but may be 'friendly' in energy saving and environmental pollution within China. Dietzenbacher *et al.* (2012) conduct a 'cost-benefit' analysis by investigating the economic 'gains' and environmental 'pains' from outsourcing to China, their results show that both the 'gains' and the 'pains' are smaller for processing exports than those for non-processing exports, yet, by taking their ratio (or cost-benefit ratio), it turns out that processing export is much more favorable than non-processing exports type. The cost-benefit ratio of the former is 0.19, and that of the latter is 0.29. Their results also show that China's exports is responsible for 12.6% of the production-related CO_2 emissions in 2005, much lower than other researches, for example, Weber *et al*. (2008) report that exports are responsible for about 33% of the production-related CO_2 emissions in 2005 (the contribution is 21% in 2002). The most important reason is that Weber *et al*. do not make distinction of processing exports thus may overestimate the contribution in CO_2 emissions of China's export.

In this paper, we focus on the energy consumption intensity of different exports type of China. Due to the large portion of imported intermediate inputs, processing exports use much lower ratio of China's domestic intermediate inputs, in most cases, typically involve the input of Chinese labor for assembly, for example in the type of processing with customer's materials[3]. The Chinese part of the production chain of these goods is relatively short when compared to the production of non-processing exports. The energy consumption of processing export is expected to be relative little, while in current national input-output table of China, processing export is 'hidden' in the whole production. As a consequence, it is important to make a distinction between processing exports and non-processing exports when calculating the energy consumption intensity by different exports type. In this paper, we employed a non-competitive input-output model capturing China's processing trade, of which China's domestic production is divided into three parts: production for domestic use only, processing exports, non-processing exports and other production of FIEs, to conduct comparative analysis on energy consumption intensity of different production activities. Due to data limits, we proposed two kinds of treatment to estimate the total energy consumption coefficients by different production type.

[3] Processing trade includes two types: processing with imported materials (PIM) and processing with customer's materials (PCM), in which PIM is the main form, accounting for more than 70% of processing trade value (for example in 2002, 73%).

The rest of the paper is organized as follows. In section 2, we introduce the methodology. In this section, two kinds of input-output (IO) models related to energy consumption are presented, "ordinary" IO model and a non-competitive IO model capturing China's processing trade virtual water trade balance by trade type. Section 3 introduces the dataset for this paper. Section 4 provides the empirical results. Section 5 is the conclusions and discussions.

2. The Methodology

In this section, we start from an open input-output model (Leontief, 1986) with energy consumption row, the layout is listed in table 1. In this table, $\mathbf{X^D}$ and $\mathbf{X^M}$ are the domestic intermediate delivery matrix and imported intermediate delivery matrix, their elements, x_{ij}^D and x_{ij}^M, are domestic products and imported products of sector *i* that are directly consumed by sector *j*. The final demand for domestic products which cover household consumption, fixed capital formation, inventory change and exports; and imported products are given by $\mathbf{F^D}$ and $\mathbf{F^M}$ respectively, both are n×1 column vectors. $\mathbf{X'}$, $\mathbf{V}$ indicate the 1×n row vectors of gross output, value-added and $\mathbf{E}$ is the energy consumption matrix across sectors (the column denotes energy type, for example, coal, petroleum), $\mathbf{M}$ is n×1 column vector of imports.

From table 1, we have $X = X^D + F^D = A^D X + F^D$ (1)

Rewrite equation (1), we obtain $X = (I - A^D)^{-1} F^D$

where I is an identity matrix, $A^D = (a_{ij}^D)_{n\times n}$ with $a_{ij}^D = x_{ij}^D / X_j$ is the direct input coefficient matrix, its element a_{ij}^D denote the direct input of product *i* to produce one unit output of product *j*; $L = (I - A^D)^{-1}$ is Leontief inverse, with typical element l_{ij} denoting the direct and indirect input of product *i* to produce one unit output of product *j*.

Table1 An input-output table with energy consumption row

	Intermediate use	Final demand	Total output
Intermediate inputs	X^D	F^D	X

	X^M	F^M	M
Value Added	V		
Total input	*X*¢		
Energy consumption	E		

2.1 Energy consumption coefficient

Define the direct energy consumption coefficient as e_{ij}

$$e_{ij} = \frac{E_{ij}}{X_j}$$

Where e_{ij} is the direct consumption coefficient of energy i by sector j (ton/RMB), i denotes energy type, E_{ij} is volume of direct energy consumption of energy i by sector j, X_j is gross output value of sector j.

e_{ij} describes the consumption of energy i by one unit of output value of sector j. In matrix notation, this becomes:

$$e = E \cdot X^{-1} \qquad (2)$$

During the production of a given sector, it not only uses energy directly (the first item on the right of equation 3) but also needs inputs of products from other sectors, which also uses energy during their production. This is the first round of indirect energy consumption of this given sector, as shown in the second item on the right of equation (3), and the second around, the third around, and so on and so forth. In an input-output model, we could obtain the *total* energy consumption coefficient $\bar{e} = e(I - A^D)^{-1}$ as follows.

$$\bar{e}_{ij} = e_{ij} + e_{ik} \cdot a^d_{kj} + e_{ik} \cdot a^d_{ks} \cdot a^d_{sj} + e_{ik} \cdot a^d_{kr} \cdot a^d_{rs} \cdot a^d_{sj} + \cdots$$

In matrix form, we have:

$$\bar{e} = e + eA^D + e(A^D)^2 + e(A^D)^3 + \cdots = e(I - A^D)^{-1} \qquad (3)$$

Combining equations (1) and (3), total energy consumption matrix can be written as:

$$\bar{E} = \bar{e} \cdot X = eLF^D \qquad (4)$$

Where $\bar{E}$ is the matrix of total energy consumption volume; the row vector eL

is the *total* energy consumption coefficient matrix of an economy, which means the sum of direct and indirect energy consumption induced by one unit increment of final demands.

2.2 Energy consumption embodied in exports

Energy consumption embodied in exports (energy content of export) is defined as the energy consumption during producing the exported goods. Energy content of export can be expressed as:

$$E_{Ex} = \sum_{j=1}^{n} e_{ij} \cdot Ex_j = e \cdot Ex \qquad (5)$$

Where Ex_j is the export value of sector j, Ex is column vector of export.

Considering the multiplier effect, the total energy content of export can be expressed as

$$\overline{E}_{Ex} = e \cdot L \cdot Ex \qquad (6)$$

2.3 Energy consumption coefficient by production category

As stated earlier, the processing export and non-processing export have quite different input structure, thus their energy consumption coefficient should be quite different too. How to track the variations between the two export types? In this section, we will investigate the energy consumption coefficient and energy content by export category by employing a non-competitive input-output model capturing China's processing trade in table 2 (Lau, *et.al*., 2006; Lau, *et.al*, 2007).

Table 2. Non-competitive Input–output table capturing China's processing trade with energy consumption

		Production for Domestic Use	Processing export	Non-processing export and other FIEs	Domestic Final Demand	Export	Total output/import
Domestic intermediate inputs	Production for Domestic Use	X^{DD}	X^{DP}	X^{DN}	F^{D}	*0*	X^{D}
	Processing export	*0*	*0*	*0*	*0*	EX^{P}	X^{P}
	Non-processing export and other FIEs	X^{ND}	X^{NP}	X^{NN}	F^{N}	EX^{N}	X^{N}

Imported intermediate inputs	X^{MD}	X^{MP}	X^{MN}	F^{M}		X^{M}
Value added	V^{D}	V^{P}	V^{N}			
Total input	$X^{D'}$	$X^{P'}$	$X^{N'}$			
Energy consumption	E^{D}	E^{P}	E^{N}			

Notes: D =production for domestic use; P = production for processing exports; N = production for non-processing exports and other production of FIEs; X^{DD} means the matrix of intermediate delivery within D, X^{DP} means the matrix of intermediate delivery from P to D, and so forth; nergy E^{D}, E^{P}, E^{N} is the energy consumption matrix of D, P and N respectively.

In table 2, China's domestic production is divided into three parts. The first one is production for domestic use only in China denoting D; the second one is production for processing exports denoting P; the third one is production for non-processing exports and other production of FIEs (Foreign-Invested Enterprises) denoting N. Here 'other production of FIEs' refers to that is used domestically in China. Although a large percentage of the products by FIEs are directly exported, some of their products are also used for domestic intermediate inputs or used for domestic final demand in China, which are listed as 'other production of FIEs'. In this table, we do not put FIEs' products that are used into production for domestic use due to the following two reasons: firstly, some of 'other production of FIEs' is used to produce exported commodities and indirectly exported. In order to lower costs, some FIEs do not directly use their processing imports to 'produce' exported goods but transfer them to other FIEs who are responsible for the re-processing or assembly and then exporting the finished products, which are listed as indirect exports and meanwhile classified as non-processing export; secondly and also the most important reason, most of 'other production of FIEs' are composed of components, parts, materials from import and thus their input structure is quite different from those production for domestic use which are mainly conducted in domestic enterprises, but more similar to that of exports.

From table 2, we have the direct energy consumption coefficient of sector i in D, P and N respectively as follows:

$$e_{ij}^{D}=\frac{E_{ij}^{D}}{X_{j}^{D}},e_{ij}^{P}=\frac{E_{ij}^{P}}{X_{j}^{P}},e_{ij}^{N}=\frac{E_{ij}^{N}}{X_{j}^{N}}$$

Where $E_{ij}^{D},E_{ij}^{P},E_{ij}^{N}$ denotes the energy consumption of energy *i* by sector *j* within *D*, *P* and *N*, respectively. The total energy consumption of each production category could be given by:

$$E^{*}=e^{*}\cdot L^{*}\cdot Ex^{*}$$

where $e^{*}=(e^{D},e^{P},e^{N})$, e^{D},e^{P},e^{N} are the matrices of direct energy consumption coefficients of *D*, *P* and *N*, with $e_{ij}^{D},e_{ij}^{P},e_{ij}^{N}$ as their elements respectively.

In the new model capturing processing trade, the direct input coefficient A^{D} is divided into nine sub-matrices, that is $A^{*}=\begin{bmatrix}A^{DD} & A^{DP} & A^{DN}\\ 0 & 0 & 0\\ A^{ND} & A^{ND} & A^{NN}\end{bmatrix}$, thus:

$$L^{*}=\begin{bmatrix}I-A^{DD} & -A^{DP} & -A^{DN}\\ 0 & I & 0\\ -A^{ND} & -A^{ND} & I-A^{NN}\end{bmatrix}^{-1}=\begin{bmatrix}B^{DD} & B^{DP} & B^{DN}\\ B^{PD} & B^{PP} & B^{PN}\\ B^{ND} & B^{ND} & B^{NN}\end{bmatrix}$$

$$Ex^{*}=(Ex^{D},Ex^{P},Ex^{N})$$

Where Ex^{D},Ex^{P},Ex^{N} are row vectors of the export by production for domestic use only, production for processing export, production for non-processing exports and other FIEs.

Due to data limits, we could not obtain the energy consumption data by processing exports and non-processing exports, so it is not possible to get the energy consumption coefficient from statistical database. We proposed two kinds of treatment to estimate the direct energy consumption coefficients by different production type.

The first treatment is that we assume the direct energy consumption coefficient is identical, that is equal to the average calculated from the “ordinary” input-output table as shown in table 1. Then the total energy consumption coefficients of *D*, *P* and *N*, denoting as U^{D},U^{P},U^{N}, can be obtained as follows:

$$U^D = e^D B^{DD} + e^P B^{PD} + e^N B^{ND}$$
$$U^P = e^D B^{DP} + e^P B^{PP} + e^N B^{NP} \quad (7)$$
$$U^N = e^D B^{DN} + e^P B^{PN} + e^N B^{NN}$$

The second treatment is separate direct energy consumption coefficients, we need to adjust based on some assumptions. As Dietzenbacher, *et. al* (2012) pointed out, for *P*, its production relies heavily on imported inputs (i.e. processing imports) and some labor for assembly for example. Only a very small part of its production chain is situated in China, in contrast to production in class *D* where a large part of the production chain is in China. Therefore it seems that the energy consumption should be lower in *P* is relatively smaller than that in *D* and *N*. While since we have no data source on energy consumption of the three different production categories, we calculate in two different ways. The first one is to assume that the direct energy consumption coefficients of *D*, *P* and *N* are identical, that is, we use $e^D = e^P = e^N = e$, where e is the vector of direct energy consumption coefficients in "ordinary" input-output tables shown in table 1.

The second way is that we use separate energy consumption coefficients. The idea would be that a lot of domestic inputs indicate much domestic activity thus need more energy, correspondingly, if most intermediate inputs are imported, it may cause much smaller domestic chain effect, i.e., the energy consumption coefficient of *P* should be the smallest in the three production categories, that of *D* be the highest and that of *N* takes the middle position. In "ordinary" IO table with imports separated from the domestic deliveries, the total domestic intermediate inputs could be expressed as $r = uA^D$, where u is the summation vector. Then, we calculate the total domestic intermediate inputs for the three separate production types (see table 2). That is:

$$r^{\mathrm{D}} = u(A^{\mathrm{DD}} + A^{\mathrm{ND}}), \quad r^{\mathrm{P}} = u(A^{\mathrm{DP}} + A^{\mathrm{NP}}) \quad \text{and} \quad r^{\mathrm{N}} = u(A^{\mathrm{DN}} + A^{\mathrm{NN}})$$

Next we define the direct energy consumption coefficients according to the amount of domestic inputs. That is:

$$e_{ki}^D = (r_i^D / r_i)e_{ki}, \quad e_{ki}^P = (r_i^P / r_i)e_{ki} \quad \text{and} \quad e_{ki}^N = (r_i^N / r_i)e_{ki} \quad (8)$$

Where *k* denotes energy types.

3. Data Description

We use two kinds of tables: one is China's energy input-output tables of 2002 and 2007, from which we obtain the average energy consumption coefficient; the other is the non-competitive input-output tables capturing China's processing export of 2002 and 2007.

The energy input-output tables of 2002 and 2007 are compiled based on China's national input-output table with 42 sectors, it consists of 44 sectors, of which 9 sectors are energy sectors including: coal, crude oil, natural gas, hydropower, thermal power, petroleum, coke, heating power, liquefied gas (Xia, *et al*. 2012). While due to date limits, in these tables, most of the service sectors are aggregated into one sector excluding transport and post, wholesale and retail trade. The non-competitive input-output tables capturing China's processing export of 2002 and 2007, however, completely matches the sector classification of national input-output tables with 42 sectors (NBS, 2006; 2009), in which service sectors are remained. For the sake of analysis, we have to make adjustment of sector classification to the two tables to match each other, finally we have 28 sectors. The sector classification is listed in the APPENDIX table 1.

4. Empirical analysis

4.1 Energy consumption coefficient by production type

Figure 1 presents the total energy consumption coefficient by production type by sector (calculated from equation 7 when assuming the direct energy consumption coefficient is identical, see 'national average' column in appendix table 2). It gives the energy consumption of per unit of the domestic final demands (such as household consumption, government expenditures and investment) and to per unit of the exports. The results show that total energy consumption coefficients of processing export are the lowest in both years. Take the ratio of total energy consumption coefficients between non-processing exports and processing exports in 2002 for example, it ranges from 1.09 to 4.81 across sectors. Particularly, as far as the sectors with a large proportion of processing export are concerned, such as Telecommunication, computer and other electronic equipment (sector 20); Electric equipment and machinery (sector 19), per unit of non-processing exports has much higher total energy consumption, 4.81 times and 4.51 times that of processing exports. Please see appendix table 3 and 4 for numbers.

By using the direct energy coefficient obtained from equation (8), the direct energy coefficients are listed in appendix table 2, we get similar results from the perspective of the trends, as shown in figure 2. Yet, the differences are that the gap of total energy consumption coefficient between non-processing exports and processing exports becomes much larger, take 2002 for example, the ratio ranges from 1.30 to 7.49, that is to say, to produce per unit non-processing export we have to use as high as 7.49 times of energy compared with that of per unit processing export, at the maximum. Again, for the sector such as Telecommunication, computer and other electronic equipment; Electric equipment and machinery, the energy consumption gap between the two kinds of export are quite large, per unit of their non-processing exports are 7.48 times and 6.07 times that of their processing exports, respectively. From this viewpoint, processing export is 'energy-efficient' than non-processing exports.

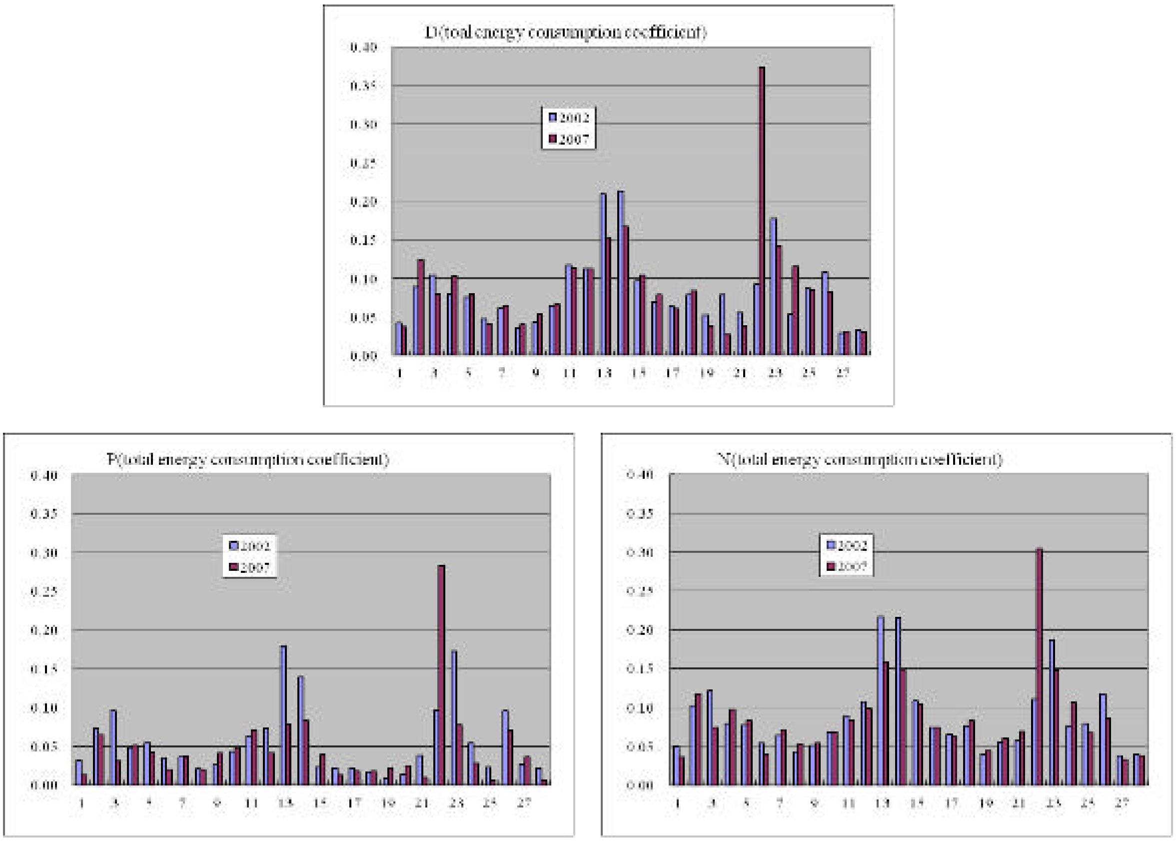

Figure 1 Total energy consumption coefficient by production category based on identical direct energy consumption coefficient (ton/thousand Yuan)

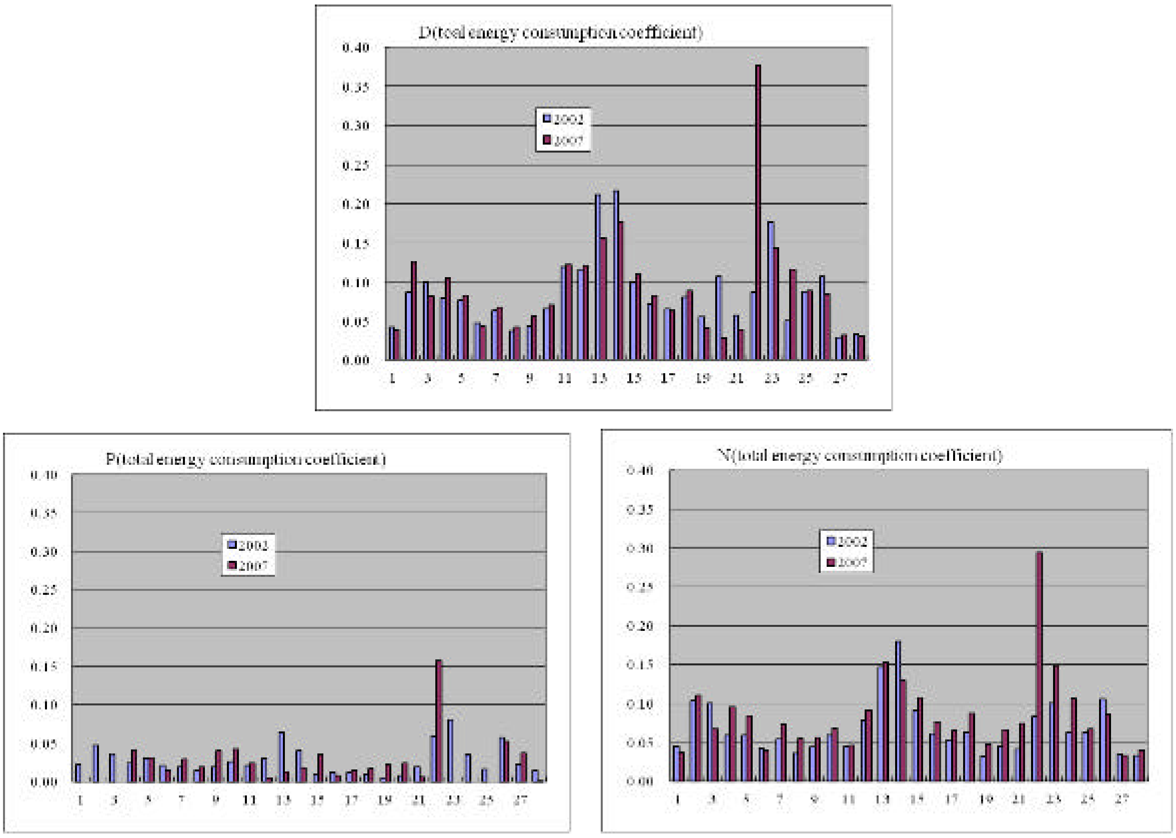

Figure 2 Total energy consumption coefficient by production category based on seperate direct energy consumption coefficient (ton/thousand Yuan)

Over time from 2002 to 2007, the total energy consumption evolution varies both by sector and by production type. Several trends could be observed: 1) Though the direct consumption coefficients of most sectors dropped from 2002 to 2007 on average, while sector 2(coal mining, washing and dressing), 11(petroleum processing, coking and nuclear fuel processing), 22(electricity and heating power production and supply), 25(Construction). It should be noted that the above four sectors are traditionally energy intensive sectors, which closely related to the high growth rate of investment in fixed capital since 2001. 2) By sector, for China's 'traditional' large-scale exports goods, for example sectors 7(textiles), 18(Electric equipment and machinery), 19(Telecommunication, computer and other electronic equipment) and 20(Instruments, meters, cultural and office machinery), the total energy consumption coefficients of which during 2002 and 2007 of both processing export and non-processing exports increased, no matter calculated by identical or separate direct energy coefficients. For other sectors, mostly the total energy consumption coefficients decreased while with no notable consistency between processing and non-processing exports; 3) The gap of total energy consumption coefficient between non-processing exports and processing export shrank due to the increasing ratio of domestic inputs for processing exports, except strange numbers of several sectors. For example, in terms of separate direct energy consumption coefficients, sector 7(textiles), the ratio of total energy consumption coefficients between non-processing exports and processing exports dropped from 2.96 to 2.51, sector 18(Electric equipment and machinery) from 6.07 to 5.23, sector 19 (Telecommunication, computer and other electronic equipment) from 7.49 to 2.16, sector 20 (Instruments, meters, cultural and office machinery) from 5.80 to 2.75. In terms of identical direct energy consumption coefficient, the trend is similar, but for sector 7 and 18, the ratio slightly went up, from 1.79 to 1.92 and from 4.51 to 4.60 respectively.

4.2 Energy consumption at aggregate level by production type

The results for total energy consumption by production type of 2002 and 2007 are listed in table 3 and table 4. The most remarkable findings show that as far as exports is concerned, the export value of processing export accounts for 92.8 percent of that for non-processing export in 2002, its total energy consumption, however, only accounts for 22.0 percent of that by non-processing export based on separate direct energy consumption coefficients, and a little bit higher (33.6 percent) when calculated by identical direct energy consumption coefficients. As mentioned before, though the value-added generated by China's processing export is much less than that by non-processing export, while concerning the ratio of value-added generated by processing export to non-processing export, it reaches to 0.371, which is much higher than the total energy consumption ratio between the two types. We also obtain similar results by energy type, for example, coal and petroleum. The ratio of total coal consumption of processing exports to that of non-processing exports is 0.350 (identical direct energy consumption coefficient). The ratio of total petroleum consumption of processing exports to that of non-processing exports is 0.339 (identical direct energy consumption coefficient). The aggregate results convey the same information that processing export is 'energy-efficient', though relatively low economy-inefficient, when compared to non-processing exports and production for domestic use. For 2007, the results report the same trend. Different from that of 2002, the proportion of processing export to non-processing exports dropped 0.273

percentage point, while in terms of total energy consumption, the P/N ratio does not change much with separate coefficients, which may show that the energy non-processing products become relatively ‘cleaner’ than that of 2002.

At the level of sectors, take the results based on identical direct energy consumption coefficient as an example. Telecommunication and computer manufacturing (sector 19, which includes electronic equipment), the processing export value of which accounts for 28.7% of China’s total processing export, is one of the most ‘energy-efficient’ sectors when compared to its export value. Although the processing export of this sector is 6 times that of non-processing export in term of exports value, the total energy consumption of the former export type is only 3.5 times that of the latter export type. Other ‘energy-efficient’ sectors include Instruments, meters, cultural and office machinery (sector 20), Electric equipment and machinery (sector 18), metal products (sector 15), Common and special equipment (sector 16), Transport equipment (sector 17). The processing export share of the above six sectors is 55.6% of China’s total processing export value.

Table 3 Results at the aggregate level, total energy consumption, value-added generated by *D, P, N* in 2002 (by final demand type)

	Domestic		*Export*		
	D	***N***	***P***	***N***	***P/N***
Total energy consumption					
separate coefficients	581269.3	749042.9	25955.1	118202.3	**0.220**
identical coefficients	573388.1	722561.2	38831.9	115435.5	**0.336**
Total coal consumption					
separate coefficients	227831.3	31554.9	10301.5	45630.2	**0.226**
identical coefficients	224318.6	30699.4	15708.1	44860.0	**0.350**
Total petroleum consumption					
separate coefficients	101866.4	8699.0	5116.1	20414.9	**0.251**
identical coefficients	101902.3	8427.8	6564.4	19358.0	**0.339**
Exports value			1489.26	1604.99	**0.928**
Value added generation	9156.91	708.27	444.87	1200.06	**0.371**

Notes: Energy consumption is in thousand ton (toc), coal consumption and petroleum consumption are in thousand ton[4]; Exports value and values added (generated by the exports) are in billion RMB yuan; identical coefficients stand for identical direct energy consumption coefficient, separate coefficients denote different direct energy consumption coefficient obtained from equation (8)

Table 4 Results at the aggregate level, total energy consumption, value-added generated by *D, P, N* in 2007 (by final demand type)

	Domestic		*Export*		
	D	***N***	***P***	***N***	***P/N***
Total energy consumption					
separate coefficients	691569.6	102804.4	33272.1	147575.1	**0.225**
identical coefficients	664924.2	103344.9	41398.0	146594.7	**0.282**
Total coal consumption					
separate coefficients	210400.5	47447.5	9782.0	39864.7	**0.245**
identical coefficients	285879.0	60302.9	15937.2	56628.8	**0.281**
Total petroleum consumption					
separate coefficients	85723.5	5518.1	3152.4	24855.3	**0.127**

[4] Here the unit of coal and petroleum are not standard coal, so it is incomparable between the sum of these two energy types and total energy consumption.

identical coefficients	142288.4	11251.8	7018.1	36879.8	**0.190**
Exports value			1474.4	2252.0	**0.655**
Value added generation	10876.04	969.25	527.68	1678.25	**0.314**

5. Conclusions and discussions

In this paper, we investigate the energy consumption differences of China among different production type in an input-output framework. And in order to make comparison by production type, particularly between processing export and non-processing export, we employ a non-competitive input-output model capturing China's processing trade, in which China's domestic production is divided into three parts: production for domestic use only, processing export, non-processing export and others of FIEs. The typical feature of processing exports can be made visible in this table, which makes possible for us to separately analyze the energy consumption of different production types. Based on the data of 2002 and 2007, we provide some empirical results. The results show that although processing export generates much less value-added for China, it is somewhat 'energy efficient' when considering both total energy consumption coefficient and total energy consumption. The total energy consumption coefficients of processing export are much lower than that of non-processing export and production for domestic use only, especially for those sectors which are usually considered as high value-added products like telecommunication equipment, computer and other electronic equipment; electric equipment and machinery, which at the same time also contribute most to China's processing export value (processing export of the above two sectors accounts for 37.7% of China's total processing export).

Based on the results, we argue that processing exports is a good way to some extent for China, at least currently and in the near future, to choose since it is 'energy efficient' due to the shorter domestic production chain in China. Economics deals with scarcity. China is now facing increasing pressure on energy shortage when compared to its rapid economic growth, thus the proper way is to consider from economic benefits and energy-saving performance. Recently there are some debates on processing export, some researchers or officials said that since processing export is relatively inefficient in generating value-added when compared with non-processing export, its development should be controlled. We agree that it is suitable to reduce the percentage of energy-intensive sectors in processing export, while for those sectors that can take full use of China's endowments, for example, labor-intensive products, we have no reason to put more limits, on the contrary, it is recommended to take some measures for their sustainable developments.

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APPENDIX Table 1 Sector Description and concordance with National IO table of China

Code	Description	Code	Concordance with national IO table
1	Agriculture	1	Agriculture
2	Coal mining, washing and processing	2	Coal mining, washing and processing
3	Crude petroleum and natural gas products	3	Crude petroleum and natural gas products
4	Metal ore mining	4	Metal ore mining
5	Non-ferrous mineral mining	5	Non-ferrous mineral mining
6	Manufacture of food products and tobacco processing	6	Manufacture of food products and tobacco processing
7	Textile goods	7	Textile goods
8	Wearing apparel, leather, furs, down and related products	8	Wearing apparel, leather, furs, down and related products
9	Sawmills and furniture	9	Sawmills and furniture
10	Paper and products, printing and record medium reproduction	10	Paper and products, printing and record medium reproduction
11	Petroleum processing, coking and nuclear fuel processing	11	Petroleum processing, coking and nuclear fuel processing
12	Chemicals	12	Chemicals
13	Nonmetal mineral products	13	Nonmetal mineral products
14	Metals smelting and pressing	14	Metals smelting and pressing
15	Metal products	15	Metal products
16	Common and special equipment	16	Common and special equipment
17	Transport equipment	17	Transport equipment
18	Electric equipment and machinery	18	Electric equipment and machinery
19	Telecommunication, computer and other electronic equipment	19	Telecommunication, computer and other electronic equipment
20	Instruments, meters, cultural and office machinery	20	Instruments, meters, cultural and office machinery
21	Other manufacturing products	21+22	Other manufacturing products
22	Electricity and heating power production and supply	23	Electricity and heating power production and supply
23	Gas production and supply	24	Gas production and supply
24	Water production and supply	25	Water production and supply
25	Construction	26	Construction
26	Transport and warehousing and post	27+28	Transport and warehousing and post
27	Wholesale and retail trade	30	Wholesale and retail trade
28	other services	29+sum(31.	other services

APPENDIX Table 2 Direct energy consumption coefficient by production type based on seperate direct energy consumption coefficient (ton/thousand yuan RMB)

Sector Code	2002				2007			
	National Average	D	P	N	National Average	D	P	N
1	0.0165	0.0163	0.0097	0.0215	0.0126	0.0126	0.0000	0.0123
2	0.0556	0.0540	0.0326	0.0691	0.0643	0.0646	0.0000	0.0559
3	0.0845	0.0799	0.0505	0.1346	0.0311	0.0317	0.0000	0.0241
4	0.0307	0.0308	0.0123	0.0296	0.0170	0.0171	0.0069	0.0137
5	0.0341	0.0346	0.0170	0.0343	0.0180	0.0184	0.0061	0.0170
6	0.0169	0.0166	0.0083	0.0183	0.0079	0.0084	0.0023	0.0068
7	0.0209	0.0222	0.0072	0.0221	0.0143	0.0155	0.0054	0.0138
8	0.0051	0.0057	0.0023	0.0057	0.0034	0.0037	0.0012	0.0037
9	0.0076	0.0079	0.0032	0.0081	0.0053	0.0058	0.0030	0.0048
10	0.0242	0.0256	0.0114	0.0257	0.0172	0.0192	0.0093	0.0153
11	0.0485	0.0524	0.0128	0.0308	0.0593	0.0673	0.0119	0.0223
12	0.0538	0.0568	0.0188	0.0484	0.0380	0.0436	0.0016	0.0300
13	0.1545	0.1564	0.0675	0.1524	0.0716	0.0738	0.0056	0.0642
14	0.1253	0.1284	0.0313	0.1151	0.0732	0.0791	0.0080	0.0528
15	0.0132	0.0143	0.0026	0.0135	0.0078	0.0083	0.0025	0.0078
16	0.0105	0.0112	0.0026	0.0097	0.0064	0.0071	0.0006	0.0058
17	0.0099	0.0104	0.0025	0.0092	0.0044	0.0048	0.0010	0.0043
18	0.0057	0.0069	0.0014	0.0057	0.0030	0.0036	0.0007	0.0030
19	0.0033	0.0048	0.0004	0.0031	0.0024	0.0029	0.0016	0.0033
20	0.0054	0.0161	0.0019	0.0097	0.0042	0.0035	0.0024	0.0075
21	0.0221	0.0234	0.0109	0.0215	0.0054	0.0053	0.0006	0.0075

22	0.0663	0.0604	0.0536	0.0817	0.2178	0.2189	0.0915	0.2059
23	0.1248	0.1256	0.0920	0.1233	0.0776	0.0777	0.0000	0.0774
24	0.0346	0.0312	0.0240	0.0421	0.0279	0.0280	0.0000	0.0276
25	0.0044	0.0044	0.0013	0.0039	0.0054	0.0054	0.0000	0.0037
26	0.0709	0.0700	0.0408	0.0809	0.0450	0.0453	0.0264	0.0441
27	0.0094	0.0092	0.0068	0.0117	0.0091	0.0091	0.0098	0.0085
28	0.0080	0.0079	0.0044	0.0096	0.0056	0.0054	0.0001	0.0066

APPENDIX Table 3 Total energy consumption coefficient by production category based on identical direct energy consumption coefficient (ton/thousand Yuan)

	Sector description	2002			2007		
		D	P	N	D	P	N
1	Agriculture	0.0416	0.0323	0.0486	0.0367	0.0126	0.0362
2	Coal mining, washing and processing	0.0886	0.0737	0.1026	0.1241	0.0643	0.1177
3	Crude petroleum and natural gas products	0.1041	0.0956	0.1218	0.0791	0.0311	0.0736
4	Metal ore mining	0.0795	0.0476	0.0792	0.1024	0.0507	0.0972
5	Non-ferrous mineral mining	0.0755	0.0542	0.0775	0.0798	0.0420	0.0835
6	Manufacture of food products and tobacco processing	0.0468	0.0350	0.0534	0.0408	0.0199	0.0403
7	Textile goods	0.0610	0.0357	0.0640	0.0640	0.0370	0.0711
8	Wearing apparel, leather, furs, down and related products	0.0349	0.0210	0.0430	0.0398	0.0201	0.0524
9	Sawmills and furniture	0.0427	0.0254	0.0508	0.0534	0.0413	0.0543
10	Paper and products, printing and record medium reproduction	0.0634	0.0435	0.0676	0.0660	0.0482	0.0678
11	Petroleum processing, coking and nuclear fuel processing	0.1174	0.0629	0.0895	0.1127	0.0707	0.0830
12	Chemicals	0.1118	0.0736	0.1069	0.1118	0.0411	0.0978
13	Nonmetal mineral products	0.2091	0.1794	0.2164	0.1518	0.0781	0.1584
14	Metals smelting and pressing	0.2127	0.1390	0.2150	0.1664	0.0831	0.1482
15	Metal products	0.0964	0.0228	0.1084	0.1043	0.0390	0.1042
16	Common and special equipment	0.0694	0.0215	0.0741	0.0783	0.0131	0.0738
17	Transport equipment	0.0632	0.0215	0.0655	0.0599	0.0178	0.0623
18	Electric equipment and machinery	0.0780	0.0168	0.0756	0.0834	0.0181	0.0834
19	Telecommunication, computer and other electronic equipment	0.0523	0.0082	0.0393	0.0382	0.0218	0.0442
20	Instruments, meters, cultural and office machinery	0.0784	0.0137	0.0551	0.0271	0.0247	0.0600
21	Other manufacturing products	0.0556	0.0374	0.0574	0.0379	0.0100	0.0695
22	Electricity and heating power production and supply	0.0930	0.0966	0.1108	0.3730	0.2832	0.3043
23	Gas production and supply	0.1768	0.1723	0.1873	0.1417	0.0776	0.1476
24	Water production and supply	0.0535	0.0543	0.0764	0.1149	0.0279	0.1061
25	Construction	0.0863	0.0224	0.0792	0.0849	0.0054	0.0670
26	Transport and warehousing and post	0.1079	0.0953	0.1173	0.0823	0.0700	0.0861
27	Wholesale and retail trade	0.0290	0.0270	0.0381	0.0311	0.0356	0.0330
28	other services	0.0327	0.0218	0.0395	0.0299	0.0059	0.0380

APPENDIX Table 4 Total energy consumption coefficient by production category based on separate direct energy consumption coefficient (ton/thousand Yuan)

	Sector description	2002			2007		
		D	P	N	D	P	N
1	Agriculture	0.0417	0.0258	0.0539	0.0379	0.0000	0.0369
2	Coal mining, washing and processing	0.0871	0.0515	0.1163	0.1261	0.0000	0.1108
3	Crude petroleum and natural gas products	0.0996	0.0619	0.1721	0.0813	0.0000	0.0672
4	Metal ore mining	0.0795	0.0296	0.0781	0.1049	0.0413	0.0951
5	Non-ferrous mineral mining	0.0764	0.0378	0.0781	0.0826	0.0307	0.0838
6	Manufacture of food products and tobacco processing	0.0468	0.0272	0.0552	0.0426	0.0147	0.0400
7	Textile goods	0.0632	0.0224	0.0662	0.0678	0.0290	0.0730
8	Wearing apparel, leather, furs, down and related products	0.0364	0.0186	0.0446	0.0420	0.0186	0.0551
9	Sawmills and furniture	0.0434	0.0215	0.0518	0.0560	0.0402	0.0556
10	Paper and products, printing and record medium reproduction	0.0657	0.0311	0.0699	0.0707	0.0418	0.0680
11	Petroleum processing, coking and nuclear fuel processing	0.1193	0.0280	0.0710	0.1224	0.0236	0.0463
12	Chemicals	0.1159	0.0385	0.1022	0.1215	0.0049	0.0916
13	Nonmetal mineral products	0.2113	0.0931	0.2147	0.1567	0.0123	0.1528
14	Metals smelting and pressing	0.2169	0.0454	0.2051	0.1769	0.0182	0.1298
15	Metal products	0.0988	0.0126	0.1093	0.1096	0.0347	0.1077
16	Common and special equipment	0.0712	0.0139	0.0738	0.0827	0.0075	0.0758
17	Transport equipment	0.0648	0.0143	0.0654	0.0632	0.0149	0.0646
18	Electric equipment and machinery	0.0808	0.0126	0.0763	0.0888	0.0166	0.0867
19	Telecommunication, computer and other electronic equipment	0.0555	0.0053	0.0400	0.0405	0.0218	0.0470
20	Instruments, meters, cultural and office machinery	0.1065	0.0103	0.0598	0.0277	0.0239	0.0657
21	Other manufacturing products	0.0575	0.0266	0.0572	0.0393	0.0054	0.0741
22	Electricity and heating power production and supply	0.0870	0.0863	0.1262	0.3762	0.1576	0.2935
23	Gas production and supply	0.1772	0.1424	0.1856	0.1437	0.0000	0.1487
24	Water production and supply	0.0498	0.0444	0.0839	0.1165	0.0000	0.1066
25	Construction	0.0875	0.0196	0.0792	0.0886	0.0000	0.0667
26	Transport and warehousing and post	0.1073	0.0664	0.1271	0.0847	0.0522	0.0862
27	Wholesale and retail trade	0.0290	0.0250	0.0406	0.0319	0.0372	0.0332
28	other services	0.0330	0.0187	0.0415	0.0309	0.0004	0.0402