Multi-objective Optimization of China's Export Commodity Structure Based on Non-competitive Input-Output Analysis*

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Abstract By applying a non-competitive input-output model capturing processing exports of China, this paper establishes a multi-objective programming model to optimize the export structure. In the input-output model, China's domestic production is divided into three parts, production for domestic use, processing exports, non-processing export and production for other FIEs, which makes possible to differentiate the effects of different trade patterns. Finally the paper conducts empirical analysis and obtained the optimizing export structure by export type based on data of 2002.

Key words Optimizing composition of export commodity, Input-output model of non-competitive imports, Processing export, Multi-objective programming

1 Introduction

Trade in goods and services is essentially the trade in factors of production. That means, to the exporter, when it exports goods and services to other countries, it exports resources while at the same time leaves the pollution caused by export activities at home. Similarly, the importer not only consumes foreign resources but also keeps the pollution away from its own country by importing goods or services.

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For China, its trade growth mode is quite extensive. For example, most export goods are labor-intensive, energy or resource-intensive and made by simple processing and assembly. There are still some goods that are restricted by *Technical Barriers to Trade* because of quality problems such as pesticide residues in food.

On the other hand, China has paid heavy price for extensive trade growth in resource and environment, i.e., the export goods are of high resource consumption and high pollution on average. Furthermore, these goods account for a large proportion in China's total export. According to the estimation by WTO Panel of Ministry of Environmental Protection of China, in 2005 China's foreign trade has generated 1.2 billion ton of CO_2 deficit[†], which amounts to 23% of industrial CO_2 emission that year; 5.5 million ton of SO_2 deficit, 39% of industrial SO_2 emission; and 61.5 billion ton of water deficit, 12% of the total industrial and agricultural water consumption in the same year [6].

The current composition of China's export products aggravates the shortage of China's energy supply and worsens the environment. It not only influences industrial and agricultural production, but also is harmful to people's health. Thus it is necessary to analyze the comprehensive effects of export on the economy, employment, resource and environment so as to objectively optimize the export structure. This is very significant to reduce resource consumption and environmental damage as soon as possible while ensuring the realization of socio-economic development goals.

The rest of the paper is organized as follows. Section 2 describes the methodology

[†] CO_2 deficit here means that export has brought out more CO_2 emission than import. SO_2 (water) deficit is of the similar meaning.

and the sketch of the model. Section 3 gives a detailed description of Multi-Objective Input-Output Model (MOIOM). Section 4 discusses the results for restructuring of China's exports based on several scenarios. Section 5 concludes.

2 Methodology

The composition of export commodities refers to the share of every kind of commodity in the total export and the relative relationship between different goods [1].

Multi-objective model is more in line with the real complex world since it considers the various factors comprehensively. The input-output (IO) model reflects the relationship among different sectors in the macroeconomic system, but it doesn't necessarily reach the optimum plan. Combining the two models, however, we can construct a new model utilizing the advantages of these two models, defined as Multi-Objective Input-Output Model (MOIOM). The most outstanding character of this model is that the equilibrium equation of IO model is changed to be a constraint condition. It has gained a wide application in many fields in practice.

Zhang (2001)[8] constructs a dynamic multi-objective model for a city including four objectives such as economic growth, energy input, pollution emission, as well as overall balance based on the city's 1997 IO table, she used the model to forecast its economic growth. Zhang et al. (2003) [9] establish a linear programming model to reflect the tariff adjustment based on non-competitive IO table. Jiang et al. (2002) [3] establish a multi-objective model based on input-output analysis to study the interaction among the population, resource, environment and economy.

Based on previous studies, this paper is to discuss the effects of export on economy,

employment, energy and water consumption, as well as pollution emission in the framework of non-competitive input-occupancy-output model. We establish the so-called MOIOM to optimize the composition of export goods, to adjust the conflict among economic and social income, resource shortage and environmental pollution so as to promote the sustainable development of the growth mode of China's foreign trade.

3 MOIOM

The input-occupancy-output model of non-competitive import type capturing processing trade is put forward in the study of Sino-US trade imbalance (Lau *et al.*, 2006). By this model, one can accurately compute not only the effects of export on domestic value-added, employment and pollution, but also the amount of resources embodied in various export commodities. It provides a clear theoretical framework for researching how to optimize the composition of export goods. The table layout of this model is given in Appendix table 1.

In this extended table, in order to capture China’s special production structure, the domestic production of China is divided into three parts, i.e., production for domestic use, processing exports, non-processing exports and production for other FIEs (Foreign Invested Enterprises), which are denoted by D, P and N respectively.

In this table, the extended direct consumption coefficient matrix can be denoted as:

$$\overline{A}=\begin{pmatrix} A^{DD} & A^{DP} & A^{DN} \\ A^{PD} & A^{PP} & A^{PN} \\ A^{ND} & A^{NP} & A^{NN} \end{pmatrix}$$

where A^{ij} is the direct consumption coefficient matrix between type i and type j

$(i, j = D, P, N)$.

Then we derive the extended total requirement coefficient matrix $\bar{B} = (I - \bar{A})^{-1}$, where I is the unit matrix of the same order as $\bar{A}$.

Let e, the column vector of export structure, represent decision variable, whose element i is e_i and it satisfies $\sum_{i=1}^{n} e_i = 1$.

In the Eleventh Five-Year Plan, China has set forth the targets of reducing energy consumption per unit of GDP by 20%, major pollutant emission (SO_2 and COD) per unit of GDP by 10% and of increasing the proportion of the value-added of the tertiary industry in GDP by 3 percentage point by the year 2010, compared with the levels in 2005.

According to this plan and considering the effects of export on economy, resources, environment and employment, the paper sets up principles of evaluating the pros and cons of the export structure. We establish a MOIOM based on the non-competitive IO model capturing processing export to optimize the composition of export goods, with a group of socio-economic development goals to be the objective functions and with the economic operation environment to be the constraint conditions.

3.1 Objective Function

We need to consider four aspects, i.e. economic growth, employment, resources and environment when setting the objective functions in order to ensure the sustainable development of export trade. Therefore, we set forth the following five optimizing principles:

(i) Maximization of economic benefit

The primary purpose of optimizing export structure is to obtain economic income as high as possible. In the IO table, it means maximizing the total domestic value-added by optimizing export structure, i.e. $\max B_V e$, where $B_V = A_V \bar{B}$ and A_V is the row vector of direct value-added coefficient.

(ii) Energy conservation principle

Energy is the material basis for economic and social development. In the increasingly tight situation of energy supply in China, the export of energy-intensive goods will only worsen the domestic energy shortage. So it is necessary to try to avoid the loss of domestic energy when upgrading export structure. Namely, we should try to minimize the energy consumption by export, i.e. $\min B_E e$, where $B_E = A_E \bar{B}$ and A_E is the row vector of direct energy consumption coefficient.

(iii) Pollution emission reduction principle

With the rapid export growth, a noteworthy problem is that export goods mainly come from high-pollution industries, whose export has accelerated the deterioration of domestic environment. To change this situation, it is necessary to make the pollution content by export as low as possible. Combining the corresponding index in the Eleventh Five-Year Plan, we choose SO_2 and COD to represent waste gas and waste water. So we come to $\min B_{SO_2} e$ and $\min B_{COD} e$, where $B_{SO_2} = A_{SO_2} \bar{B}$, $B_{COD} = A_{COD} \bar{B}$ and A_{SO_2}, A_{COD} are respectively the row vector of direct emission coefficient of SO_2 and COD.

(iv) Increase of employment principle

The fact that China has a population of more than 1.3 billion people makes employment very important for its economic development and social stability. While the export enterprises have always been one of the driving force in providing job positions, so we expect them to absorb as many labor forces as possible, so as to ease the employment pressure in China. Then we set: $\max B_L e$, where $B_L = A_L \overline{B}$, A_L is the row vector of direct labor occupation coefficient.

(v) Principle of balance in industrial development

As we all know, the tertiary industry could meet the demand not only for living service of consumers to improve their living standard but also for production service of producers to improve the efficiency, so it has a strategic role in national economy. In other words, the ratio of value-added of the tertiary industry to GDP is expected to reach a certain value, like w, $\frac{\left[\hat{A}_V X\right]_T}{\left[A_V X\right]} = w$, where $\hat{A}_V$ is a diagonal matrix, the element on the diagonal is direct value-added coefficient of each industry; T means the set of sectors in the tertiary industry; X stands for the column vector of total output. The numerator of the above formula is the value-added of the optimized tertiary industry and the denominator is the optimized GDP.

3.2 Constraints

Economic and social development is inseparable from the natural and social conditions like population, resource and environment. In order to promote the comprehensive and sustainable development of economy and society, we select the following five constraints:

(i) The input-output balance constraint reflecting the interdependence of production, distribution and consumption among different national economic parts:

$$X = \left(I - \bar{A}\right)^{-1}\left(\bar{Y} + E\right) = \bar{B}\left(\bar{Y} + e\hat{E}\right)$$

where $\bar{Y}$ and E are the column vector of domestic final use and that of export, respectively; $\hat{E}$ is a scalar which denotes the total export volume.

(ii) Constraint of energy supply:

$$A_E X \le E^S$$

where E^S is the total energy supply of that year, A_E is a row vector of direct energy coefficient, i.e., energy consumption per unit of total output value.

(iii) Constraint of water supply:

$$A_W X \le W^S$$

where W^S is the total water supply of that year and A_W is the row vector of direct water consumption coefficient.

(iv) Upper and lower limit constraint of the export share of every sector:

$$l \le e \le u$$

where u and l are the column vectors of upper and lower limit of export share of every sector, respectively.

(v) Constraint of vector structure:

$$I'e = 1$$

where $I' = (1,1,\mathrm{L}\ ,1)$.

(vi) Non-negative constraint:

$$e \ge 0$$

Now we establish the MOIOM of optimizing the composition of export goods.

3.3 Solution of MOIOM

It is well known that goal programming (GP) doesn't emphasize the absolute optimality when deciding and solving. It could handle various multi-objective programming problems even without uniform units of measurement as well as problems with conflicting objectives. Besides, it is easy to solve since it is an extension of linear programming. All the above advantages make it flexible and practical in diverse fields. So it is chosen to solve this MOIOM.

Specifically, we first need to set expectation value for each objective function in reference to the Eleventh Five-Year Plan.

The expected changes ("+" for up and "-" for down) for GDP, energy consumption per unit of GDP, emission of SO_2, emission of COD, the ratio of value-added of the tertiary industry in GDP and the employment are respectively +1%, -2%, -2%, -2%, +1%, +1%, with $OBJ1$, $OBJ2$, $OBJ3$, $OBJ4$, $OBJ5$, $OBJ6$ denoting the expected values of them respectively.

Then the original MOIOM is transformed as follows.

The objectives are:

$$\min\left[OBJ1 - B_V(\bar{Y} + e\bar{E}^{0\%})\right] \tag{1}$$

$$\min\left[\frac{B_E(\bar{Y} + e\bar{E}^{0\%})}{B_V(\bar{Y} + e\bar{E}^{0\%})} - OBJ2\right] \tag{2}$$

$$\min\left[B_{SO_2}(\bar{Y} + e\bar{E}^{0\%}) - OBJ3\right] \tag{3}$$

$$\min\left[B_{COD}(\bar{Y} + e\bar{E}^{0\%}) - OBJ4\right] \tag{4}$$

$$\min \left| \frac{\left[\hat{B}_V (\bar{Y} + e\bar{E}') \right]_T}{\left[B_V (\bar{Y} + e\bar{E}') \right]} - OBJ5 \right| \tag{5}$$

$$\min \left[OBJ6 - B_L (\bar{Y} + e\bar{E}') \right] \tag{6}$$

where: $\hat{B}_V$ is the diagonal matrix of the row vector of total value-added coefficient.

Expression (1) denotes the macro-economic objective, i.e., the economic benefits generated by export structure after optimization should be as close to $OBJ1$ as possible; Expression (2) is the energy consumption per unit of output value objective, i.e., the energy consumption per unit of output value, under the condition of export structure optimization, should not be higher than $OBJ2$; Expression (3) and (4) are the pollution emission reduction objectives, i.e., the SO_2 and COD emission, under the condition of export structure optimization, should not be higher than $OBJ3$ and $OBJ4$, respectively; Expression (5) is the balanced industrial development objective, meaning the ratio of value-added of the tertiary industry in GDP is as close to $OBJ5$ as possible, where the nominator and denominator of the first term stand for value-added of the tertiary industry and GDP, under the condition of export structure optimization, respectively; Expression (6) is the employment objective generated by export, i.e., the employment generated by export, under the condition of export structure optimization, should not be lower than $OBJ6$.

The constraints consist of two parts, the inequality constraints on the resource and the equality constraints on the objectives. They are:

$$B_E\left(\bar{Y}+e\hat{E}^0\right)\le E^S$$

$$B_W\left(\bar{Y}+e\hat{E}^0\right)\le W^S$$

$$l\le e\le u$$

$$B_V\left(\bar{Y}+e\hat{E}^0\right)+d_1^- -d_1^+ = OBJ1$$

$$\frac{B_E\left(\bar{Y}+e\hat{E}^0\right)}{B_V\left(\bar{Y}+e\hat{E}^0\right)}+d_2^- -d_2^+ = OBJ2$$

$$B_{SO_2}\left(\bar{Y}+e\hat{E}^0\right)+d_3^- -d_3^+ = OBJ3$$

$$B_{COD}\left(\bar{Y}+e\hat{E}^0\right)+d_4^- -d_4^+ = OBJ4$$

$$\frac{\left[\hat{B}_V\left(\bar{Y}+e\hat{E}^0\right)\right]_T}{B_V\left(\bar{Y}+e\hat{E}^0\right)}+d_5^- -d_5^+ = OBJ5$$

$$B_L\left(\bar{Y}+e\hat{E}^0\right)+d_6^- -d_6^+ = OBJ6$$

$$I'e=1$$

$$e,d_i^-,d_i^+\ge 0$$

where: d_i^+, d_i^- are the positive and negative deviation variables for goal constraint i respectively and I' is the summation vector.

It should be noted here that the input-output equation $\bar{B}\left(\bar{Y}+e\hat{E}^0\right)=X$ is hard constraint considering the export and the total output to be endogenous. So X can be replaced by the left side.

3.4 Data Sources

The empirical analysis of this paper is based on the 2002 non-competitive extended input-output table capturing processing trade of China which consists of 42 production sectors. The SO_2 and COD emissions of every sector refer to China Environment Yearbook 2002. The energy supply is taken from China Energy Yearbook 2000-2002, and the energy consumption of every sector refers to the extended non-competitive energy IO table constructed by Wang et al. (2009) [5]. The

water supply is taken from China Statistical Bulletin of Water 2002, and the water consumption of every sector refers to Xiang et al. (2009) [7]. Then we divide the energy consumption, water consumption and pollution emission into three parts by D, P and N in reference to Dietzenbacher et al. (2009) [2]. Other data are from China Statistical Yearbook for various years.

Notably, the energy dataset is composed of 26 sectors. To keep consistency in data, we finally aggregate 42 production sectors to 26 ones. The comparison between the two classifications is given in Appendix table 2.

4 **Results**

In the computation of GP, it is firstly required to determine the priority level for the unwanted deviation of every goal, with the minimization of a deviation in a higher priority level being infinitely more important than any deviations in lower priority levels.

Here we set four scenarios simulating different priority levels of the objective functions to get different attainment functions (See Table 1), by which the solution of GP is transformed to solve a single-objective linear programming problem.

Table 1. The attainment functions under different orders of priority levels

Scenario	Objective Function						Attainment Function
	(1)	(2)	(3)	(4)	(5)	(6)	
I	P_1	P_2	P_3	P_3	P_5	P_4	$\min f = P_1 d_1^- + P_2 d_2^+ + P_3 (d_3^+ + d_4^+) + P_4 d_6^- + P_5 (d_5^- + d_5^+)$
II	P_2	P_1	P_3	P_3	P_5	P_4	$\min f = P_1 d_2^+ + P_2 d_1^- + P_3 (d_3^+ + d_4^+) + P_4 d_6^- + P_5 (d_5^- + d_5^+)$
III	P_4	P_2	P_1	P_1	P_5	P_3	$\min f = P_1 (d_3^+ + d_4^+) + P_2 d_2^+ + P_3 d_6^- + P_4 d_1^- + P_5 (d_5^- + d_5^+)$
IV	P_3	P_2	P_4	P_4	P_5	P_1	$\min f = P_1 d_6^- + P_2 d_2^+ + P_3 d_1^- + P_4 (d_3^+ + d_4^+) + P_5 (d_5^- + d_5^+)$

In Table 1, P_i is the priority level i, with $P_i \gg P_{i+1}$ meaning the priority level i being infinitely more important than the priority level $(i+1)$. Since B_{SO_2} and B_{COD} share the same unit, i.e., ton per 10 thousands, d_3^+ and d_4^+ can be summed up directly which implies that it is equally important to reduce the emission of SO_2 and COD.

4.1 General results

To solve the above four GP models separately, we can reach the optimized export structure under different scenarios (See Table 2).

Table 2. The optimized composition of export goods under different scenarios (%)

Sector	Actual Composition	Scenario			
		I	II	III	IV
1	1.53	1.33	1.31	1.27	0.95
2	0.51	0.50	0.49	0.50	0.40
3	0.39	0.23	0.29	0.17	0.39
4	0.06	0.19	0.06	0.14	0.07
5	0.49	0.82	0.69	0.79	0.89
6	2.89	2.72	2.74	2.74	3.70
7	8.79	8.25	8.26	8.27	8.83
8	8.97	9.01	9.03	9.03	9.08
9	2.15	2.09	2.11	2.11	2.31
10	3.19	1.52	1.52	1.51	0.84
11	0.85	0.00	0.00	0.00	0.02
12	7.03	5.27	5.27	5.28	5.22
13	1.35	0.00	0.00	0.00	0.02
14	1.49	0.00	0.00	0.00	0.02
15	3.44	2.10	2.12	2.12	2.02
16	4.22	3.23	3.25	3.25	3.11
17	2.11	1.19	1.21	1.21	1.01
18	6.57	5.50	5.52	5.52	5.36
19	16.05	14.83	14.85	14.85	14.74
20	4.79	4.26	4.28	4.26	3.78
21	1.36	2.04	2.13	2.06	1.69
22	0.02	0.00	0.00	0.00	0.00

23	0.16	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00
25	0.34	0.36	0.39	0.38	0.95
26	21.23	34.56	34.47	34.55	34.59

From Table 2, the sectors whose export shares need to be reduced is characterized firstly by higher pollution sectors such as Paper and products, printing and record medium reproduction (sector 10), then by higher energy or resource consumption like Nonmetal mineral products (sector 13), and by lower value-added due to a large number of processing export, just as Transport equipment (sector 17).

For simplicity, we define such sectors as Type I.

Obviously, the export shares of Petroleum processing, coking and nuclear fuel processing (sector 11), Nonmetal mineral products (sector 13), Metals smelting and pressing (sector 14) all need to be reduced to 0% under the former three scenarios. Although the unavoidable reasons like data or model error make it somehow idealistic, the results show a clear trend that it is urgent to reduce the export proportions of these sectors since they make tremendous negative impact on domestic energy and environment.

In a word, the characteristics of Type I is not consistent with the optimized principles put forward earlier. So it is imperative to lower their export share.

Sectors whose export proportions need to be increased include Metal ore mining (sector 4), Non-ferrous mineral mining (sector 5), Wearing apparel, leather, furs, down and related products (sector 8), Other manufacturing products (sector 21), Construction (sector 25) and Services (sector 26).

The sector of Services (sector 26) needs to increase mostly. Based on 2002 IO table,

its actual export share is 21.23%, and after optimization it reaches about 34.50%. A well-known reason is that Services is not only of low energy consumption and pollution but also of high value-added and employment, thus its export makes positive comprehensive effects. So it is necessary to expand the export of Services[‡]. Besides, considering the particularity of service trade in the IO table, it is also necessary to develop the export of sectors closely related to Services and with lower energy consumption and pollution, like Wearing apparel, leather, furs, down and related products and Other manufacturing products. We call these sectors as Type II.

Type III refers to sectors with inconsistent changing trends under different scenarios, including Manufacture of food products and tobacco processing (sector 6), Textile goods (sector 7) and Sawmills and furniture (sector 9).

These three sectors have a common feature, that is, their export shares all need to be reduced under the first three scenarios and to be increased under the fourth one. This is because that the main characteristics of these sectors are labor-intensive. Taking Textile goods for example, by 2008, it has absorbed 20 million labors and is the most labor-absorbing sector in manufacturing sectors[§].

Type III is of great importance to employment but in the mean time it is with high energy consumption and pollution. Importantly, these sectors are of long industry chain, which can lead to huge harm to energy and environment.

Overall, the export share of Type I should be reduced and that of Type II be raised

[‡] "The export of Services" in IO table is different from the commonly said service trade. The former consists of the value-added of transportation sectors and commercial industries that goods trade arouses in the transformation from off shore price to producer price.
[§] Source: http://bt.xinhuanet.com/2009-01/22/content_15525693.htm

under the current technical conditions. From the dynamic point of view, it is important to update the industry structure by improving the energy efficiency and reducing the pollution emission of sectors that are with positive economic and employment effects. As for those sectors with lower energy consumption and pollution, it is important to strengthen self-innovation to increase the technology content.

4.2 Results of differentiating trade patterns

When differentiating processing and non-processing export, the optimized export compositions of every sector in the two trade patterns are also different (see Table 3).

Table 3. The optimized results under different trade patterns (%)

Type	Sector	Processing Export						Non-processing Export					
		Actual	Scenario				Optimized	Actual	Scenario				Optimized
			I	II	III	IV			I	II	III	IV	
A	10	2.29	1.48	1.49	1.48	0.84	−	0.90	0.04	0.04	0.03	0.00	−
	11	0.20	0.00	0.00	0.00	0.00	−	0.65	0.00	0.00	0.00	0.02	−
	12	2.82	1.97	1.98	1.98	1.99	−	4.21	3.30	3.29	3.30	3.24	−
	13	0.24	0.00	0.00	0.00	0.00	−	1.11	0.00	0.00	0.00	0.02	−
	14	0.57	0.00	0.00	0.00	0.02	−	0.92	0.00	0.00	0.00	0.00	−
	15	1.59	0.88	0.89	0.89	1.04	−	1.86	1.22	1.22	1.23	0.98	−
	16	1.61	1.01	1.03	1.02	1.06	−	2.61	2.21	2.22	2.22	2.04	−
	17	1.05	0.41	0.42	0.42	0.46	−	1.06	0.78	0.79	0.79	0.55	−
	18	4.35	3.65	3.66	3.66	3.77	−	2.22	1.85	1.86	1.86	1.59	−
	19	13.77	12.89	12.90	12.90	13.10	−	2.28	1.94	1.95	1.95	1.65	−
	20	4.37	4.25	4.26	4.26	3.67	−	0.43	0.02	0.02	0.00	0.11	−
	22	0.02	0.00	0.00	0.00	0.00	−	0.00	0.00	0.00	0.00	0.00	——
	23	0.00	0.00	0.00	0.00	0.00	——	0.15	0.00	0.00	0.00	0.00	−
B	2	0.00	0.22	0.23	0.22	0.21	+	0.51	0.27	0.26	0.28	0.19	−
	3	0.00	0.13	0.21	0.07	0.29	+	0.39	0.10	0.08	0.10	0.10	−
	4	0.00	0.16	0.04	0.13	0.05	+	0.06	0.03	0.03	0.01	0.02	−
	6	0.76	0.38	0.39	0.39	0.44	−	2.13	2.35	2.35	2.36	3.26	+
	7	2.54	1.90	1.91	1.91	2.17	−	6.25	6.35	6.35	6.35	6.66	+
	8	4.16	3.72	3.73	3.73	3.89	−	4.81	5.29	5.30	5.30	5.19	+
	9	0.89	0.52	0.53	0.53	0.58	−	1.26	1.57	1.58	1.58	1.73	+
	21	0.75	0.17	0.18	0.18	0.39	−	0.62	1.87	1.95	1.88	1.30	+
C	25	0.00	0.00	0.00	0.00	0.00	——	0.34	0.36	0.39	0.38	0.95	+

	26	5.94	11.11	11.08	11.11	11.10	+	15.29	23.45	23.39	23.44	23.49	+
D	1	0.04	0.09	0.08	0.02	0.12	~	1.49	1.23	1.23	1.26	0.83	−
	5	0.15	0.21	0.05	0.16	0.18	~	0.34	0.61	0.63	0.62	0.71	+
Sum		48.13	45.15	45.07	45.05	45.39	−	51.87	54.85	54.93	54.95	54.61	+

Note: In Table 3, the minus "-"means a decline of the export share after optimizing, the plus "+" an increase, "——" keeping to be zero, and "~"uncertain trend.

From Table 3, according to the changing trend the sectors can be generalized to four categories: Type A, Type B, Type C and Type D.

Export proportion of Type A should be reduced in both trade patterns after optimization, including Paper and products, printing and record medium reproduction (sector 10), Petroleum processing, coking and nuclear fuel processing (sector 11), Chemicals (sector 12), Nonmetal mineral products (sector 13), Metals smelting and pressing (sector 14), Metal products (sector 15), Common and special equipment (sector 16), Transport equipment (sector 17), Electric equipment and machinery (sector 18), Telecommunication equipment, computer and other electronic equipment (sector 19), Instruments, meters, cultural and office machinery (sector 20), Electricity and heating power production and supply (sector 22), Gas production and supply (sector 23).

Moreover, the processing export shares of sector 11, 13, 22 and the non-processing export shares of sector 14, 23 are all reduced to 0% after optimization.

The major characteristic of Type B is that the export proportions of these sectors show opposite changing trends in two patterns. Sectors whose processing export share needs to be reduced while that of the non-processing export should be increased include Manufacture of food products and tobacco processing (sector 6), Textile goods (sector 7), Wearing apparel, leather, furs, down and related products (sector 8),

Sawmills and furniture (sector 9) and Other manufacturing products (sector 21). Different from the above, sectors including Coal mining, washing and processing (sector 2), Crude petroleum and natural gas products (sector 3) and Metal ore mining (sector 4) need to increase their processing export share while reduce the non-processing export share.

Type C refers to sectors whose export share should be raised in at least one trade pattern, including Construction (sector 25) and Services (sector 26).

Sectors in Type D show an uncertain changing trend at least in one pattern, like Agriculture (sector 1) and Non-ferrous mineral mining (sector 5).

For Type A, it is obvious that these sectors are either resource-intensive or of high pollution or of low domestic value-added. By optimization, their export proportion are reduced, some even to 0%, which is in accordance with the optimization principles. At the same time, some sectors with higher value-added, such as Common and special equipment, Transport equipment and Electric equipment and machinery, should improve the technical level and energy efficiency.

As to Type B, the reason that different optimization results are obtained under different trade patterns is that the production structure of these sectors in two patterns are not the same. Taking Crude petroleum and natural gas products for example, the total value-added of non-processing export and production for other FIEs is 1.5 times as much as that of processing trade, but its total energy consumption per unit of GDP, the total SO_2 emission per unit of GDP and the total COD emission per unit of GDP are 3.1 times, 10.2 times and 2.4 times as much as that of the processing export,

respectively. From this we can see that the positive comprehensive effects of processing export of this sector is better than that of the non-processing export, so that its processing export share should be raised.

For Services, its energy consumption and pollution emission level in both patterns are lower than that of the average, while its employment and value-added coefficients are equal to or higher than that of the average. Therefore it is comprehensively beneficial to increase its export share in both patterns.

In total, the share of processing export should be cut down by 3 percentage point, while that of the non-processing export should be accordingly increased by 3 percentage point after optimization, since it has better effects than processing export in general.

5 Conclusion

This paper has established a multi-objective input-output model for optimizing the composition of export goods in China. Based on the results, several policy implications could be proposed.

First, implement the export tariff rebate policy appropriately and timely to control the export of high energy consumption and heavy pollution.

Second, improve the pricing mechanism of export products. The price of export products should reflect the cost of various elements consumed, in particular the cost of resources and environment.

Third, promote the upgrading of processing trade. A problem of the processing export is that at present it is limited to simple processing and assembly which is of

quite low domestic value-added. But based on our analysis, the processing export is better than the non-processing export in energy efficiency and pollution emission. So enterprises committing the processing trade should be supported to innovate to enhance their contribution to GDP.

Fourth, develop service trade. On one hand, since the sector of Services is a sector with multiple benefits, its direct export should be encouraged. On the other hand, the trade of sectors that are in close relation to Services (transport and commerce services especially) should also expand since they have indirect contributions.

To sum up, it is favorable and necessary to optimize the composition of export goods by setting appropriate principles. This is a useful attempt to promote the sustainable development of trade.

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Appendix

Table 1. China's non-competitive input-output table capturing processing trade

Input \ Output	Intermediate Use			Final Use		Gross Output or Imports
	Production for Domestic Use (D)	Processing Export (P)	Non-processing Export and production for other FIEs (N)	Domestic Final Use	Export	
	1…n	1…n	1…n			

Input	Domestically Intermediate Inputs	Production for Domestic Use (D)	1 ⋮ n	X_{ij}^{DD}	X_{ij}^{DP}	X_{ij}^{DN}	$\overline{Y}_i^D$	0	X_i^D
		Processing Export (P)	1 ⋮ n	0	0	0	0	E_i^P	X_i^P
		Non-processing Export and production for other FIEs (N)	1 ⋮ n	X_{ij}^{ND}	X_{ij}^{NP}	X_{ij}^{NN}	$\overline{Y}_i^N$	E_i^N	X_i^N
	Intermediate Inputs from Imports		1 ⋮ n	X_{ij}^{MD}	X_{ij}^{MP}	X_{ij}^{MN}	$\overline{Y}_i^M$	0	M_i
	Value-added			V_j^D	V_j^P	V_j^N			
	Gross Input			X_j^D	X_j^P	X_j^N			
Occupancy	Employees			L_j^D	L_j^P	L_j^N			
	Resources			R_j^D	R_j^P	R_j^N			

Notes: The superscript DD stands for domestic products used by domestic use, DP domestic products used by processing exports, DN domestic products used by non-processing exports and production for other FIEs, and so forth. X_{ij}^{DD}, X_{ij}^{DP} and X_{ij}^{DN} denote the intermediate input from the domestic products of sector i to D, P and N of sector j respectively; X_{ij}^{ND}, X_{ij}^{NP} and X_{ij}^{NN} indicate the deliveries of the non-processing export and production for other FIEs of sector i to D, P and N of sector j respectively; $\overline{Y}_i^D$, $\overline{Y}_i^P$ and $\overline{Y}_i^N$ denote the final domestic use of D, P and N of sector i respectively; E_i^P and E_i^N are the volume of processing export and non-processing export of sector i respectively; X_i^D, X_i^P and X_i^N are the output of D, P and N of sector i respectively; V_j^D, V_j^P and V_j^N are the value-added of D, P and N of sector j respectively; L_j^D, L_j^P and L_j^N are the labour occupancy of D, P and N of sector j respectively; R_j^D, R_j^P and R_j^N are the resource occupancy of D, P and N of sector j respectively.

Source: Lau, L., Chen, X., Cheng, L. et al. (2006) The Estimation of Domestic Value-Added and Employment Generated by U.S.-China Trade, Working Paper, Institute of Economics, Chinese University of Hong Kong, 2.

Table 2. Comparison table of classification between 26-sector and 42-sector of 2002 IO table in China

26-sector		42-sector	
Code	Sector	Code	Sector
01	Agriculture	01	Agriculture
02	Coal mining, washing and processing	02	Coal mining, washing and processing
03	Crude petroleum and natural gas products	03	Crude petroleum and natural gas products
04	Metal ore mining	04	Metal ore mining
05	Non-ferrous mineral mining	05	Non-ferrous mineral mining
06	Manufacture of food products and tobacco processing	06	Manufacture of food products and tobacco processing
07	Textile goods	07	Textile goods
08	Wearing apparel, leather, furs, down and related products	08	Wearing apparel, leather, furs, down and related products
09	Sawmills and furniture	09	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 equipment, computer and other electronic equipment	19	Telecommunication equipment, computer and other electronic equipment
20	Instruments, meters, cultural and office machinery	20	Instruments, meters, cultural and office machinery
21	Other manufacturing products	21	Other manufacturing products
		22	Scrap and waste
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	Services	27	Transport and warehousing
		28	Post
		29	Information communication, computer service and software
		30	Wholesale and retail trade
		31	Accommodation, eating and drinking places

		32	Finance and insurance
		33	Real estate
		34	Renting and commercial service
		35	Tourism
		36	Scientific research
		37	General technical services
		38	Other social services
		39	Education
		40	Health service, social guarantee and social welfare
		41	Culture, sports and amusements
		42	Public management and social administration