Economic Growth Centre
Economics, School of Social Sciences
Nanyang Technological University
14 Nanyang Drive
Singapore 637332

MEASUREMENT AND DECOMPOSITIOM OF EMBODIED CARBON EMISSIONS IN THE EXPORT OF ELECTROMECHANICAL PRODUCTS FROM CHINA TO SOUTH KOREA

Dan Men
Qing Zhang

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HSS-04-90A
Tel: +65 67906073
Email: D-EGC@ntu.edu.sg

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Measurement and Decompositiom of Embodied Carbon Emissions in the Export of Electromechanical Products from China to South Korea

Dan Men[ab], Qing Zhang[a]

[a]School of Economics and Management, Nanchang University, Nanchang, Jiangxi, PR China; [b]Economic Growth Centre, School of Social Science, Nanyang Technological University, Singapore

Abstract: This paper uses MRIO model to measure the embodied carbon emissions of China's exports to South Korean electromechanical products in 2005-2014, and uses LMDI method to decompose the overall scale of embodied carbon emissions from electromechanical products exports and the factors affecting carbon emissions from various sub-projects contained in electromechanical products from three aspects: scale effect, structural effect and intensity effect. As a result: ① The embodied carbon emissions caused by China's export of electromechanical products to South Korea is relatively large, indicating that China bears the carbon emissions of South Korean consumers while conducting trade. ②China's export of embodied carbon to South Korean electromechanical products showed a trend of first rise and then fall, implying that China's energy conservation and emission reduction policies has played a good role. ③The scale effect has the highest contribution rate to the export of embodied carbon emissions from China to South Korean electromechanical products and plays a positive driving role. Structure and intensity effect play a reverse inhibition. This means that if China want to lower its embodied carbon emissions from exports and raise its voice in international climate negotiations, it will need to promote a system of world carbon-emissions accountability based on consumer responsibility, at the same time, we will further implement energy conservation and emission reduction policies, adjust the structure of export products, and optimize the structure of energy utilization.

Keywords: China and South Korea; electromechanical product export; embodied carbon emissions; MRIO model; LMDI method

1. Introduction

Today, little or no countries and groups can deny the impact of carbon emissions on global climate change. Initially, studies on carbon emissions mainly focused on the impact of human activities or policy-making in a single country. For example, through estimating the CO_2 emissions of 17 different types of household behaviors, Thomas et al. (2009) pointed out that the implementation of an active green lifestyle could reduce 123 million tons of CO_2 emissions per year in the United States, accounting for 7% of the total CO_2 emissions, with almost no reduction in family well-being. Similarly, Suzuki et al. (1995) estimated direct and indirect CO_2 emissions from the construction of various types of housing in Japan using the sector classification Input/Output Tables. Wang et al. (2005) used LMDI method to calculate the change trend of China's CO_2 emissions from 1957 to 2000, and pointed out that a series of energy policies launched by the Chinese government, including improving energy intensity, fuel conversion and penetration of renewable energy, had a positive impact on the reduction of CO_2 emissions. However, with the advancement of economic globalization and the signing of a series of global greenhouse gas emission reduction agreements, developed countries gradually transfer high pollution and high carbon intensive industries to developing countries and evade their carbon emission responsibility by expanding imports, which leads to carbon leakage. (Peters, G. P. and Hertwich, E. G., 2008). Using developing countries as Pollution Havens undermines the effectiveness of global emission reduction agreements, because the impacts of climate change are global, not just for a single country or region. Although emission reduction still focuses on reducing carbon emissions from the source of producers, researchers are paying more and more attention to carbon transfer related to global supply chain, consumer policy and international trade (Kehan He and Edgar G. Hertwich, 2019). For example, Peters & Herwick (2008) estimated the CO_2 emissions embodied in 87 countries' international trade, which shows that most developed countries are net import countries of CO_2 emissions embodied in international trade. In 2001 alone, Annex B countries of Kyoto Protocol imported more than 530 million tons of CO_2 emissions embodied. Nakanoi et al. (2009) also pointed out that at the end of the 1990s, more than half of the increase in global CO_2 emissions could be attributed to the final demand of OECD countries. G6 countries were the main net importers of CO_2, while the BRICs and Indonesia were the major exporters. Chen & Chen (2011) divided global CO_2 emissions into three parts: G7 countries, BRICs countries and other countries and they found that CO_2 emissions embodied in trade imported to G7 countries in 2004 were 1.53 billion tons, accounting for 36% of their trade emissions, while the exports of BRICs countries in the same period were 1.37 billion tons, accounting for 51% of their trade emissions. These research evidences prove that the phenomenon that developed countries transfer carbon emission pressure to developing countries through international trade is long-term and widespread. Although some developed countries have claimed that they have reduced carbon emissions in recent years, however, this is only because the current carbon emission system allows these countries to transfer carbon intensive products to other countries. As the research of kanemoto et al. (2014) shows, if we recalculate CO_2 emissions adjusting for trade, the emissions of developed countries should have increased, not decreased.

In 2012, China's total import and export trade exceeded that of the United States for the first time, becoming the world's largest trading country. However, the growth rate of China's total foreign trade also includes China's total carbon emissions. As early as 2006, China's total carbon emissions had surpassed the United States and became the world's largest carbon emitter. Although the speed and level of China's energy efficiency improvement are obvious, since 1990, the global CO_2 emissions per unit output have decreased by 15% on average, while China has decreased by about 50%. As China has become the "factory of the world", it has undertaken considerable carbon emissions for other countries in global trade. Based on the multi regional input-output model (MRIO), Zhang et al.(2014) measured China's carbon emissions from 1997 to 2007 and found that the expansion of foreign trade, especially the rapid increase of exports, was the main reason for the rapid increase of China's CO_2 emissions. Lin & Sun's (2010) research also shows that the increase of China's CO_2

emissions is not only related to domestic consumption, but also related to external demand. In fact, China's CO_2 emissions based on consumption are far lower than production-oriented emissions. In 2005, China exported 3.357 billion tons of CO_2 emissions through foreign trade, while avoided by imports was 2.333 billion tons. Generally speaking, the CO_2 emissions exported through international trade usually account for about 20% of China's total domestic emissions, mainly from labor-intensive and energy-intensive industries (Sato,2014). Besides, the empirical research based on the bilateral and multilateral trade between China and other countries or regions further refines CO_2 emissions embodied in China's foreign trade and provides more detailed driving factors. Han et al. (2019) pointed out that China has been a net exporter of CO_2 emissions in Sino-US trade for a long time due to its high level of carbon emissions per unit of value added. Pang et al. (2017) found that China is also a net exporter of CO_2 emissions embodied in the trade between China and Japan, and pointed out that China should adjust the export trade structure and develop high-output and low-energy consumption industries. Yan et al. (2012) pointed out that the growth of China's export scale to the European Union makes China in the position of CO_2 emission transfer country, and part of China's CO_2 emission is caused by the demand of EU for China. Meng et al. (2019) found that in China's international trade with India, South Korea and other countries along the "One Belt And One Road", the embodied carbon emissions showed a net export trend. Li et al. (2018) also found that Japan, the United States, South Korea, Russia and Canada have reduced CO_2 emissions and gained environmental benefits in the aquatic products trade with China.

China has become South Korea's largest trading partner for many years, and South Korea is also the main export destination of China (Ministry of Commerce, P.R.China, 2019). In 2015, South Korea surpassed Japan and became China's second largest trading partner for the first time. The trade between China and South Korea not only accelerates the cross-border transfer of commodity production and consumption, but also leads to the redistribution of carbon emissions. Yu & Chen (2017) analyzed the carbon transfer in the trade between China and South Korea from 2000 to 2010 through the traditional competitive input-output trade, and pointed out that the deficit of CO_2 emissions embodied in China's trade with South Korea was not from the trade surplus, but related to the structure of import and export trade. The trade between China and South Korea effectively reduced the global carbon emissions and relieved the pressure of China's carbon emissions. However, Zhang et al.(2019) used the non competitive MRIO table to point out that the traditional input-output model may overestimate the carbon emissions, and the technology structure effect of import and the scale effect of export are the main reasons for China's CO2 emissions embodied surplus. On the whole, there are little research on the CO_2 emissions embodied in the trade between China and South Korea, which do not match the rapidly increasing trade scale between China and South Korea. Therefore, this paper uses MRIO model to calculate the CO_2 emissions embodied in the electromechanical products export from China to South Korea, which accounts for more than 50% of the trade volume between China and South Korea. And then, the LMDI method is used to decompose the influencing factors of China's export of electromechanical products to South Korea into scale effect, structure effect and intensity effect in order to understand the impact of CO_2 emissions embodied in trade, and to provide the basis for China to further implement emission reduction policies.

The structure of this paper is as follows: the second section explains the MRIO method, LMDI technology and data processing in detail. The third section briefly analyzes the calculation results of CO_2 emissions embodied in the trade of electromechanical products between China and South Korea, and discusses the driving factors of CO_2 emissions embodied in the trade. Finally, the fourth section summarizes the conclusions and gives possible policy suggestions.

2. Methodology and data

2.1 MRIO model for measuring CO_2 emissions embodied in the trade

The multi-regional input-output (MRIO) model can quantify and analyze the relationship between production sectors with different resource utilization status in different countries, so as to trace the carbon emissions of products to their countries of origin. MRIO table divides the import and export products into intermediate products and final consumption, thus reflecting the internal correlation of input and output between different departments in different countries (regions). Therefore, in this paper, the world input-output table is redrawn according to the needs.

Table 1: Simplified World MRIO Table

		Intermediate investment				Final consumption				Total output
		Country1	Country2	...s...	Country N	Country1	Country2	...s...	Country N	
Intermediate input	Country 1	x_{11}	x_{12}	...	x_{1n}	y_{11}	y_{12}	...	y_{1n}	X_1
	Country 2	x_{21}	x_{22}	...	x_{2n}	y_{21}	y_{22}	...	y_{2n}	X_2
	...r...	...	...	x_{rs}	...	...	...	y_{rs}	...	...
	Country N	x_{n1}	x_{n2}	...	x_{nn}	y_{n1}	y_{n2}	...	y_{nn}	X_n
Added value		...	...	...	..					
Total investment		X_1	X_2	...	X_n					

The world MRIO table can be expressed as follows:

$$\begin{Bmatrix} X_1 \\ X_2 \\ X_3 \\ \vdots \\ X_n \end{Bmatrix} = \begin{Bmatrix} A_{11} & A_{12} & A_{13} & \cdots & A_{1n} \\ A_{21} & A_{22} & A_{23} & \cdots & A_{2n} \\ A_{31} & A_{32} & A_{33} & \cdots & A_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_{n1} & A_{n2} & A_{n3} & \cdots & A_{nn} \end{Bmatrix} \begin{Bmatrix} X_1 \\ X_2 \\ X_3 \\ \vdots \\ X_n \end{Bmatrix} + \begin{Bmatrix} \sum Y_{1j} \\ \sum Y_{2j} \\ \sum Y_{3j} \\ \vdots \\ \sum Y_{nj} \end{Bmatrix} \tag{1}$$

X_i is the total output of the countries in the world; A_{ij} is the direct consumption coefficient of country j to country i, that is, the production unit product of country j directly consumes the product quantity of country i, and the matrix A is the direct consumption coefficient matrix. A_{ii} represents the investment of intermediate products in various industries within countries. ΣY_{1j} represents the final product of each country for domestic consumption. The domestic final product y can be divided into domestic surplus consumption Y_i and export Y_{ex}. Therefore, to facilitate the calculation of a country's domestic output, X_i can be rewritten as follows:

$$X_i = (I - A_{ii})^{-1}(Y_i + Y_{ex}) \tag{2}$$

According to formula (2), we can get the CO_2 embodied emissions of a country CE_{pi}：

$$CE_{pi} = E_i X_i = E_i (I - A_{ii})^{-1} (Y_i + Y_{ex}) \quad (3)$$

E_i is the CO_2 emission coefficient of the country, where E_i can be calculated by formula $E_i = \left[\left(\sum_{g=1}^{n} CEF_g \times NCV_g \times COF_g \times \varepsilon_g \times D_j \right) / X_j \right] \times (44/12)$. CEF_g is the carbon emission factor; NCV_g is the average calorific value; COF_g is the carbon oxidation factor; ε_{gj} is the proportion of j energy consumption in the total energy consumption of g industry; D_j is the apparent consumption of j industry; X_j is the total output of j industry.

2.2 LMDI method for decomposition of influencing factors of CO_2 emissions embodied in the China's export of electromechanical products to South Korea

LMDI can decompose the change of carbon emissions into the sum of the changes of various factors through the addition decomposition method, so as to decompose the various influencing factors of carbon emissions, and analyze the contribution of the changes of various influencing factors to the change of carbon emissions.

In this paper, the CO_2 emissions embodied in the China's exports of electromechanical products to South Korea are described as identities:

$$CE_{\mathrm{me}}^{\mathrm{ex}} = \frac{CE_{me}^{ex}}{EV} \times \frac{EV}{EV_{\mathrm{me}}} \times EV_{\mathrm{me}} \quad (4)$$

In the formula, CE_{me}^{ex} is the CO_2 emissions embodied in the export trade of electromechanical products; EV is the total trade volume of electromechanical products after excluding the impact of price fluctuation; EV_{me} is the export volume of electromechanical products. At the same time, EV_{me} is used to represent the trade scale characteristics of electromechanical products, EV/EV_{me} is used to represent the trade structure characteristics of electromechanical products, and CE_{me}^{ex}/EV is used to represent the intensity of CO_2 emissions embodied in electromechanical products trade. Therefore, the driving factors of CO_2 emissions embodied in the trade of electromechanical products are decomposed into scale effect, structure effect and intensity effect. Therefore, the change of CO_2 emissions embodied in China's export of electromechanical products to South Korea in the t phase relative to the base period can be decomposed in the form of LMDI addition as follows:

$$\Delta \mathrm{CE}_{\mathrm{me}}^{\mathrm{ex}} = CE_{\mathrm{me}}^{\mathrm{ext}} - CE_{\mathrm{me}}^{\mathrm{ex0}}$$
$$= \Delta CE_{EV\mathrm{me}} + \Delta CE_{\frac{EV}{EV\mathrm{me}}} + \Delta CE_{\frac{CE_{\mathrm{me}}^{\mathrm{ex}}}{EV}} + \Delta CE_{\mathrm{rsd}} \qquad (5)$$

According to the results of Ang et al.(1998), model (5) can be deduced as follows:

$$\Delta CE_{EV\mathrm{me}} = \frac{CE_{\mathrm{me}}^{\mathrm{ext}} - CE_{\mathrm{me}}^{\mathrm{ex0}}}{\ln CE_{\mathrm{me}}^{\mathrm{ext}} - \ln CE_{\mathrm{me}}^{\mathrm{ex0}}}\left[\ln (\mathrm{EV}_{\mathrm{me}})^{t} - \ln (\mathrm{EV}_{\mathrm{me}})^{0}\right]$$
$$\Delta CE_{\frac{EV}{EV\mathrm{me}}} = \frac{CE_{\mathrm{me}}^{\mathrm{ext}} - CE_{\mathrm{me}}^{\mathrm{ex0}}}{\ln CE_{\mathrm{me}}^{\mathrm{ext}} - \ln CE_{\mathrm{me}}^{\mathrm{ex0}}}\left[\ln \left(\frac{EV}{EV\mathrm{me}}\right)^{t} - \ln \left(\frac{EV}{EV\mathrm{me}}\right)^{0}\right]$$
$$\Delta CE_{\frac{CE_{\mathrm{me}}^{\mathrm{ex}}}{EV}} = \frac{CE_{\mathrm{me}}^{\mathrm{ext}} - CE_{\mathrm{me}}^{\mathrm{ex0}}}{\ln CE_{\mathrm{me}}^{\mathrm{ext}} - \ln CE_{\mathrm{me}}^{\mathrm{ex0}}}\left[\ln \left(\frac{CE_{\mathrm{me}}^{\mathrm{ex}}}{EV}\right)^{t} - \ln \left(\frac{CE_{\mathrm{me}}^{\mathrm{ex}}}{EV}\right)^{0}\right] \qquad (6)$$

In the formula, $\Delta CE_{EV\mathrm{me}}$ 、 $\Delta CE_{\frac{EV}{EV\mathrm{me}}}$ 、 $\Delta CE_{\frac{CE_{\mathrm{me}}^{\mathrm{ex}}}{EV}}$ and respectively represent the contribution value of scale effect, structure effect and intensity effect to CO_2 emissions embodied in trade; ΔCE_{rsd} are decomposition surplus; period t and period 0 represent the reporting period and base period respectively. If the contribution value is regular, it shows that this factor has a positive driving effect on the CO_2 emissions embodied in the China's electromechanical products exports to South Korea, and increases the carbon emissions. If the contribution value is negative, it indicates that this factor has a negative inhibitory effect, which is conducive to reducing carbon emissions. At the same time, in order to better understand the impact of various factors on the CO_2 emissions embodied in the trade, this paper decomposes the driving factors of China's exports of electromechanical products to South Korea in the form of multiplication of LMDI method, and calculates the contribution rate of each factor. If the contribution rate is greater than 1, it means that the factor has a driving effect on the CO_2 emissions embodied in the export; if the contribution rate is less than 1, it means that the factor has an inhibitory effect. The calculation formula is as follows:

$$CCE_{me}^{ex}=CE_{me}^{ext}/CE_{me}^{ex0}=CCE_{EVme}\times CCE_{\frac{EV}{EVme}}\times CCE_{\frac{CE_{me}^{ex}}{EV}}\times CCE_{rsd} \quad (7)$$

In the formula, CCE_{EVme} and $CCE_{\frac{EV}{EVme}}$ and $CCE_{\frac{CE_{me}^{ex}}{EV}}$ are the contribution rates of scale effect, structure effect and intensity effect to the CO_2 emissions embodied in the export, and are the decomposition allowance .

2.3 Data preparation

(1) The data needed to calculate the CO_2 emissions embodied in the China's electromechanical products exports to South Korea by MRIO model mainly include China's input-output table, China's export volume of electromechanical products to South Korea, and CO_2 emission coefficient of China's electromechanical products. The input-output table of this paper is from the world MRIO table in WIOD database. The data from 2005 to 2014 are selected as the research object. This is the latest data that can be publicly obtained, and has been recognized by researchers. The electromechanical products studied are classified by HS code (customs code). The code "coordination" covers the two classification and coding systems of CCCN and SITC. Under this classification, electromechanical products are classified into 84-92 categories, as shown in Table 2. Their export trade volume is from uncomtrade data Library.

(2) The data needed to calculate the CO_2 emission coefficient E_i of China's electromechanical products are from the China Provincial Greenhouse Gas Inventory Compilation Guide and China Statistical Yearbook, China Energy Statistical Yearbook and 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

(3) The data required by LMDI method include the carbon emissions from China's export trade of electromechanical products to South Korea, the total and trade volume of China's export trade of electromechanical products to South Korea. The CO_2 emissions embodied in China's export trade of electromechanical products to South Korea are calculated by this paper. The required data of China's export trade of electromechanical products to South Korea are from Uncomtrade Database and China

Statistical Yearbook.

Table 2: HS code of electromechanical products

Code	Product overview
84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof
85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers; television image and sound recorders and reproducers, parts and accessories of such articles
86	Railway, tramway locomotives, rolling-stock and parts thereof; railway or tramway track fixtures and fittings and parts thereof; mechanical (including electro-mechanical) traffic signalling equipment of all kinds
87	Vehicles; other than railway or tramway rolling stock, and parts and accessories thereof
88	Aircraft, spacecraft and parts thereof
89	Ships, boats and floating structures
90	Optical, photographic, cinematographic, measuring, checking, medical or surgical instruments and apparatus; parts and accessories
91	Clocks and watches and parts thereof
92	Musical instruments; parts and accessories of such articles

Source: China HS Code, Customs , 2019

3. Results

3.1 Calculation and analysis of CO_2 emissions embodied in China's export trade of electromechanical products to South Korea

According to the China Energy Statistical Yearbook, disposable energy is divided into coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil, natural gas and electricity. Electricity is generated after consumption of other energy sources - ensuring there is no double counting. The CO_2 emission coefficient of electromechanical products in China from 2005 to 2014 is calculated by the above-mentioned CO_2 emission coefficient calculation formula. The data of carbon emission factor, average low calorific value, carbon oxidation factor, energy consumption of electromechanical products and total output of electromechanical products are shown in Table 3 and table 4.

Table 3: Data Required for Calculation of CO_2 emission coefficient

Energy	Carbon Emission Factor (kg/GJ)	Ave Low Calorific Value (kJ/kg)	Carbon Oxidation Factor	Total energy consumption in 2005-2014									
				2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
crude oil	20.0	41 816	1	1.12	1.12	1.11	1.35	0.59	0.74	0.36	0.22	0.52	0.23
Gasoline	18.9	43 070	1	116.66	118.37	150.24	156.53	183.22	196.80	171.59	157.83	149.83	144.55
kerosene	19.5	43 070	1	22.12	17.62	16.76	20.19	12.98	16.92	16.41	13.33	13.73	6.03
diesel oil	20.2	42 652	1	274.09	261.99	235.39	390.25	367.68	390.19	278.21	218.50	217.69	197.31
fuel oil	21.1	41 816	1	70.52	75.59	74.77	73.49	67.15	45.88	32.94	21.01	17.68	12.5
Coal	26.0	20 908	1	1817.3	1834.9	1837.5	2 211	2 441	2378.7	2462.5	2281.2	2559.5	2188.1
Coke	29.2	28 435	1	499.61	715.9	787.16	735.20	961.32	986.51	1267.6	1126.1	988.58	973.55
Gas	15.3	38 931	1	16.97	19.40	22.73	31.05	31.18	37.02	46.49	51.94	62.25	69.17

Source: Provincial Greenhouse Gas Inventory Compilation Guide, China Statistical Yearbook, China Energy Statistical Yearbook, 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Table 4: 2005—2014 China output of electromechanical products

(unit: 100 million yuan)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Yield	74 548.35	94 729.49	120 982.18	148 265.35	165 074.56	212 169.55	247 756.04	262 703.97	298 442.17	327 668.44

Source: China Statistical Yearbook

The calculation results of CO_2 emission coefficient of electromechanical products in China from 2005 to 2014 are shown in Table 5. From the CO_2 emission coefficient table, we can see that the overall trend of CO_2 emission coefficient of electromechanical products in China is downward, besides the the period of the global financial crisis in 2009. In this period, the Chinese government adjusted the export policy of coal and changed from export to domestic sales, which led to the oversupply of domestic coal, the decline of coal price, the rise of coal use, and the rise of carbon dioxide emission coefficient. All these show that China attaches great importance to environmental protection and energy utilization, and also shows that the emission reduction work has achieved certain results.

In the process of calculating the CO_2 emissions embodied in China's electromechanical products exports to South Korea, according to formula (3), the carbon emissions are calculated. The calculation data of China's export of electromechanical products to South Korea are from table 5 and the WIOD Database. The calculated CO_2 emissions embodied in China's exports of electromechanical products to South Korea are shown in Table 6.

Table 5: CO_2 emission coefficient of electromechanical products in China from 2005 to 2014 (unit: kgco2 / 10000 yuan)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CO_2 Emission Coefficient	897.97	777.22	628.0	587.94	595.4	464.2	420.5	356.3	317.76	262.18

Table 6: China's export trade volume of electromechanical products to South Korea and CO_2 emissions embodied in export from 2005 to 2014

Year	Export trade volume / 100 million yuan	Carbon embodied in export / 10000 tons
2005	1 096.461 2	2 070.352 4
2006	1 301.153 1	2 231.688 6
2007	1 587.447 7	2 266.055 9
2008	1 893.427 6	2 589.895 9
2009	1 798.138 8	2 268.500 8
2010	2 095.360 3	2 362.899 5
2011	2 164.934 4	2 368.0129 9
2012	2 493.961 7	2 188.349 7
2013	2 683.809 0	2 084.824 7
2014	2 832.371 5	1 769.472 2

Source: China's export trade volume of electromechanical products to South Korea is from Uncomtrade Database, and CO_2 emissions embodied in export is calculated by the author.

From the perspective of the dynamic changes of CO_2 emissions embodied in China's electromechanical products exports to South Korea, China's exports of electromechanical products to South Korea showed the characteristics of first rising and then decreasing from 2005 to 2014. The CO_2 emissions embodied in export increased from 20.7 million tons in 2005 to 25.9 million tons in 2008, reaching the highest point, and then mostly showed a downward trend. According to table 6, China's export volume of electromechanical products to South Korea shows that, affected by the lag of the financial crisis in 2008, China's export volume of electromechanical products to South Korea decreased in 2009. Therefore, the carbon emissions of China's electromechanical products exports to South Korea also decreased in 2009. In 2011, China's "12th Five Year Plan" included carbon emission indicators for the first time, further determined the goal of energy conservation and emission reduction, and China's export of electromechanical products to South Korea began to gradually reduce carbon emissions.

3.2 Decomposition of CO_2 emissions embodied in China's export of electromechanical products to South Korea

China's export of electromechanical products to South Korea implies a large amount of embodied carbon emissions, and generally presents the characteristics of first rise and then decrease. Based on the LMDI method, this paper decomposes the influencing factors of China's export of electromechanical products to South Korea from scale effect, structure effect and intensity effect.

This paper takes 2005 as the base period, according to the CE_{me}^{ex} value calculated above and the volume EV_{me} of China's export of electromechanical products to South Korea from Uncomtrade Database, we get the decomposition results of the influencing factors of China's export of electromechanical products to South Korea. Since the data EV_{me} and EV in uncomtrade database are in US dollars, they are converted into RMB according to the exchange rate between US dollar and RMB from 2005 to 2014 provided in China Statistical Yearbook, and the price index in China Statistical Yearbook is used to exclude the price changes caused by inflation, which makes the calculation more accurate.

From 2005 to 2014, China's export trade of electromechanical products to South Korea reduced 2.8662 million tons of embodied carbon emissions, of which the scale effect played a driving role and increased the carbon emissions by 18.18 million tons; the structure effect played a restraining role and reduced the carbon emissions by 6.02 million tons, and the intensity effect also played a restraining role, reducing the carbon emissions by 15.16 million tons. The scale effect has the greatest impact on China's embodied carbon emissions in the export of electromechanical products to South Korea. The expansion of China's export scale of electromechanical products to South Korea plays a strong role in promoting the embodied carbon emissions of China's electromechanical products exports to South Korea, and its contribution rate has been greater than 1, and has been rising since 2005, which shows that with the expansion of China's export scale of electromechanical products to South Korea, the embodied carbon emissions is also growing rapidly. Besides, the structural effect inhibits the emission of embodied carbon from China's export of electromechanical products to South Korea, and the contribution rate showed a generally downward trend. This result shows that the trade structure of China's export of electromechanical products to South Korea is playing a more and more important role, but its range is small. Therefore, in order to further understand the influence of various products on the structural effect under the subdivision of electromechanical products, this paper also analyzes the structural effect under the subdivision of electromechanical products in China to South Korea according to the classification of electromechanical products in Table 2.The results show that two kinds of electromechanical products such as locomotives, vehicles and their parts of railway and tramway; railway and tramway track fixed device and its parts and accessories; all kinds of mechanical (including electric machinery) traffic signal equipment and musical instruments and their parts, accessories, have a positive pulling effect on the structural effect, and show an increasing trend year by year. Among them, the export volume of locomotives, vehicles and parts of railway and tramway is large, and the pulling effect on structural effect is also obvious.Other products have a reverse inhibitory effect on structural effects, among which aircraft, spacecraft and their parts have obvious inhibitory effects. If we further strengthen the supply side reform, improve the trade structure of China's electromechanical products exports to South Korea, and improve China's production technology for railway and tramway locomotives, vehicles and their parts, carry out deep processing and realize product upgrading, which is conducive to effectively reducing the embodied carbon emissions of China's electromechanical products exports to South Korea. In the factor decomposition of China's export of electromechanical products to South Korea, the intensity effect also plays an inhibitory role, and the contribution rate is generally on the decline, indicating that the intensity effect is also playing a more and more important role in restraining the embodied carbon emissions of China's electromechanical products exports to South Korea.Therefore, the improvement of China's export structure of electromechanical products to South Korea and the reduction of CO_2 emissions embodied in export intensity jointly inhibit the growth of China's export of electromechanical products to South Korea, and the inhibition range of intensity effect is more obvious than that of structure effect. Although the growth of CO_2 emissions embodied caused by the scale effect of electromechanical products export is higher than that caused by the structural effect and intensity effect, the restraining effect of structure effect and intensity effect can effectively prevent the increasing of the embodied carbon emissions from keeping pace with the increasing of export scale.

Table 7: Decomposition results of various factors of Carbon emissions embodied in Sino-South Korea export trade of electromechanical products from 2006 to 2014

Year	Contribution value / 10000 tons					Contribution rate		
	scale effect	structure effect	Intensity effect	Annual total effect	Cumulative total effect	scale effect	structure effect	Intensity effect
2006	368.002	20.685	-227.351	161.336 4	161.336 4	1.186 7	1.009 7	0.899 7
2007	801.776	-64.701 8	-541.371	34.367 2	195.703 6	1.447 8	0.970 6	0.778 9
2008	1 267.66	-216.597	-531.517	323.839 4	519.543	1.726 9	0.910 9	0.795 3
2009	1 072.39	-700.086	-174.157	-321.395	198.148	1.640 0	0.724 0	0.922 8
2010	1 433.48	-643.809	-497.128	94.399	292.547	1.911 0	0.747 6	0.798 8
2011	1 507.45	-535.669	-674.119	5.114	297.661	1.974 5	0.785 3	0.737 7
2012	1 749.42	-709.442	-921.981	-179.664	117.997	2.274 6	0.716 6	0.648 5
2013	1 859.74	-763.316	-1 081.96	-103.529	14.468	2.447 7	0.692 5	0.594 1
2014	1 818.31	-602.637	-1 516.56	-315.353	-300.885	2.583 2	0.730 1	0.453 2

All in all, the scale effect has a positive driving effect on the CO_2 emissions embodied in electromechanical products exported from China to South Korea, and it is generally increasing year by year, with the contribution rates of more than 2 in 2012, 2013 and 2014. While, the structure effect and intensity effect have a negative inhibitory effect. And the inhibitory effect of intensity effect is more obvious than that of the structure effect.

4. Conclusions and policy implications

Through the construction of MRIO model, this paper calculates the carbon emissions embodied in the electromechanical products exported from China to South Korea from 2005 to 2014, and decomposes the influencing factors from three aspects of scale effect, structure effect and intensity effect based on LMDI method. The main conclusions are as follows:

(1) China's export of electromechanical products to South Korea has a large amount of carbon emissions embodied, which shows that part of China's CO_2 emissions are caused by foreign trade with South Korea, and indicates that China undertakes the carbon emissions of other consumers. Although foreign trade is conducive to promoting China's economic growth, it also increases the pressure on China's ecological environment, and brings disadvantages to China in the international climate negotiations. Therefore, the study of China's carbon emissions caused by foreign trade is of great significance to change China's position in international climate negotiations and promote the reclassification of the world's responsibilities for carbon emissions.

(2) The CO_2 emissions embodied in China's export of electromechanical products to South Korea showed a trend of rising first and then decreasing, which indicated that China's energy conservation and emission reduction policy had played a good role, but the total amount of CO_2 emissions embodied in China's electromechanical products exports to South Korea was still large.

(3) In the process of decomposing the influencing factors of China's export of electromechanical products to South Korea, it is found that the scale effect has the highest contribution rate to the embodied carbon emissions, and plays a positive driving role. However, the structural effect and intensity effect have a reverse inhibitory effect, and the intensity effect is more obvious than the structural effect. Moreover, the impact of these three effects on embodied carbon emissions is

increasing year by year.

The policy implications are as follows:

(1) Establishing an emission accounting system based on consumption responsibility. At present, the international emission accounting system based on production responsibility makes many developed countries realize the transfer of carbon emissions through industrial transfer and expansion of imports from developing countries, thus reducing their own carbon emission responsibility, which is not conducive to the realization of global emission reduction goals. Therefore, it is of great significance for the realization of the global emission reduction goal by constructing the emission accounting system based on the consumption responsibility that can reasonably calculate the carbon emission of each country and divide the carbon emission responsibility of each country.

(2) Further implement energy conservation and emission reduction policies in China. In recent years, China has been carrying out energy conservation and emission reduction policy, and has achieved certain results, but the unclear target of the initial implementation of the policy makes the effect of emission reduction poor. Therefore, China can further implement energy conservation and emission reduction policies for products with strong driving effect of carbon emissions embodied, such as railway and tramway locomotives, vehicles and their parts, so as to realize the reduction of carbon emission in China's production.

(3) Adjust the structure of export products and optimize the structure of energy utilization. Since the implementation of China's basic national policy of opening to the outside world, foreign trade has played an important role in promoting China's and the world's economic growth. Therefore, it is unrealistic to reduce export carbon emissions by reducing the scale of foreign trade. However, the structural effect and intensity effect have an inhibitory effect on China's export of electromechanical products to South Korea. In aspect of structural effect, China can guide the export focus from locomotives, vehicles and parts of Railways and Tramways to aircraft, spacecraft and its parts with relatively low energy consumption. In aspect of intensity effect, China can reduce the using proportion of coal, coke and diesel, optimize the

energy utilization structure in order to reduce the carbon emission of production.

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References

Ang, B.W., Zhang, F.Q., Choi, K.H.1998. Factorizing Changes in Energy and Environmental Indicators Through Decomposition. Energy, 23: 489-495.

Chen, Z.M., and Chen, G.Q. 2011.Embodied Carbon Dioxide Emission at Supra-National Scale: A Coalition Analysis for G7, BRIC, and The Rest of The World. Energy Policy, 39: 2899-2909.

Han, Zhong, and Wang, Gang. 2019. Calculation of Embodied Energy and Carbon Emissions in Sino US Trade Based on Multi Regional Input Output Model. Research progress of climate change, 15: 416-426. (In Chinese)

K. Kanemoto, D. Moran, M. Lenzen, A. Geschke. 2014. International Trade Undermines National Emission Reduction Targets: New Evidence From Air Pollution. Global Environmental Change, 24:52-59.

Kehan, He., Edgar, G.Hertwich.2019.The Flow of Embodied Carbon Through The Economies of China, The European Union, and The United States. Resources, Conservation and Recycling,145:190-198.

Li, Chen., Cong, Rui., Shao, Guilan. 2018. Research on The Transfer of Embodied Carbon Emissions in China's Aquatic Products Trade Based on MRIO Model and LMDI Method. Resource Science, 40: 1063-1072. (In Chinese)

Lin, Boqiang., and Sun, Chuanwang. 2010. Evaluating Carbon Dioxide Emissions in International Trade of China. Energy Policy, 38: 613-621.

Meng, Fanxin., Su, Meirong., Hu,Yuanchao. 2019. Research on the Carbon Transfer of Trade Embodied in China and Typical Countries Along the “Belt and Road”. China's Population, Resources and Environment, 29: 18-26. (In Chinese)

Ministry of Commerce, P.R. China. 2019. South Korea Trade News, Beijing: China.

Nakano, S., A. Okamura, N. Sakurai, M. Suzuki, Y. Tojo, and N. Yamano. 2009. The Measurement of CO_2 Embodiments in International Trade: Evidence From the Harmonised Input–Output and Bilateral Trade Database, OECD Science. Technology and Industry Working Papers, Paris: OECD.

Pang, Jun., Jin, Jiarui., Gao, Xiaomo. 2017. Decomposition Analysis of Embodied Carbon and Effect in Sino-Japanese Trade Based on MRIO Model. Proceedings of the Annual Conference of Science and Technology of the Chinese Society of Environmental Sciences, 1:783-789. (In Chinese)

Pang,Jun.,and Zhang, Junzhe. 2014. Embodied Carbon Emissions from Sino-European Trade and Its Influencing Factors - Analysis Based on MRIO Model and LMDI. International Economic and Trade Exploration, 30: 51-65. (In Chinese)

Peters, G. P., and Hertwich, E. G. 2008. CO_2 Embodied in International Trade with Implications for Global Climate Policy. Environmental Science and Technology, 42: 1401–1407.

Sato, M. 2014. Embodied Carbon in Trade: A Survey of the Empirical Literature. Journal of Economic Surveys, 28: 831-861.

Suzuki, Michiya., Tatsuo, Oka., Kiyoshi, Okada. 1995. The Estimation of Energy Consumption and CO_2 Emission Due to Housing Construction in Japan. Energy and Buildings, 22:165-169.

Thomas, Dietz., Gerald, T. Gardner., Jonathan., Gilligan., Paul, C. Stern., Michael, P. Vandenbergh. 2009. Household Actions Can Provide a Behavioral Wedge to Rapidly Reduce US Carbon Emissions. Proceedings of the National Academy of Sciences, 106 :18452-18456.

Wang, Can., Chen, Jining.,Zou, Ji. 2000. Decomposition of Energy-Related CO_2 Emission in China: 1957-2000. Energy, 30:73-83.

Yan, Yunfeng., Zhao, Zhongxiu., Wang, Ran. 2012. The Embodied Carbon in Sino-European Trade and Policy Implications - An Empirical Study Based on Input-Output Model. Finance and Trade Research, 23:76-82. (In Chinese)

Yu, Yang., Chen, Feifan.Research on Carbon Emissions Embodied in Trade Between China and South Korea. Atmospheric Pollution Research,8:56-63.

Zhang, Bingbing., Zhai, Guangmeng., Sun, Chuanwang & Xu, Shuhua. 2019. Re-Calculation, Decomposition and Responsibility Sharing of Embodied Carbon Emissions in Sino-Korea Trade: A New Value-Added Perspective. Emerging Markets Finance and Trade.

Zhang, Zengkai., Guo, Ju'e., Geoffrey, J.D. Hewings. 2014. The Effects of Direct Trade within China on Regional and National CO_2 Emissions. Energy Economics, 46: 161-175.