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HOW IMPORTANT IS MARKET-DISTRIBUTION TO CHINA'S EXPORTS OF LOW-CARBON GOODS?*

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The objective of this study is to gauge the potential and constraints of China's low-carbon goods exports by first evaluating its exports performance, then finding the engines for exports growth, using the constant market share (CMS) analysis. The results of the empirical analysis covering the period 2006-2015 indicate that the market distribution effect is the main determinant for China's low-carbon goods exports growth. While the diversification of China's low-carbon commodity composition has the potential to increase China's low-carbon export growth, its low-carbon goods exports appear to be not competitive against the exports from other competitor countries during the period of analysis.

Keywords: Low-carbon Goods Exports, Nationally Determined Contributions (NDC), Market Distribution of Exports, Constant Market Share (CMS) Analysis, China.
JEL Classification: F18, Q42

1. INTRODUCTION

It has been argued in the literature that countries tend to face environmental degradation in the initial phase of economic development, as the priority will always be on economic growth rather than environmental protection (Baldwin, 1995; and Stern, 2014). Considering London in the 18th century, for example, during the first industrial revolution coal was predominantly used in economic activities to stimulate economic growth. However, the large-scale use of coal polluted London. In 1952, the Great Smog killed more than 4,000 people over several days (Fenger, 2009). Examples can also be drawn from China. China's economy increased nearly 62 times with around 6 times

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growth in CO2 emission between 1979 and 2016 (World Bank, 2015). There is a strong evidence that CO2, one of the most important greenhouse gases (GHG), will cause various environmental problems, including increasing the earth's temperature, raising the sea level, reducing the ozone layer, and spreading of many diseases. This will not only affect people's wellbeing, but also negatively influence economic growth as well. At the turn of the 21st century, the World Bank estimated disease and death from air pollution in China would represent annual losses of 2-3% of GDP. Thus, it is imperative for the emerging economies to delink growth from environmental degradation and to achieve sustainable economic development.

In this context, the United Nations Framework Convention on Climate Change Conference (UNFCCC) held in Paris in December 2015 reached an agreement on post-2020 global climate regimes. In preparation, countries had outlined what actions would they take under such agreement, known as Intended Nationally Determined Contributions (NDCs), dealing with environmental issues (Qi and Weng, 2016). China released its NDC, which included various goals to mitigate climate change, such as decreasing the CO2 intensity of GDP, improving non-fossil energy's share, peaking CO2 emissions, and increasing forest stock volume (Xinhua, 2014). This ambitious goal means that the non-fossil energy supplies by 2030 would be 7-8 times that of 2005 (He, 2015), and that the demand for low-carbon goods would be increasing.

This transition to more and more non-fossil energy supplies not only in China, but also in countries across the globe, is centred on the innovation and dissemination of low-carbon goods and processes for which international trade plays a crucial role, particularly for developing countries where technical innovations are costlier (Jha, 2009). It is interesting to learn from a recent study by the U.K. Joint Environmental Markets Unit (UKJEMU) that about 50% of total environmental goods to be used within 2030 are yet to be created, which emphasizes the urgent need for research and development (R and D) to develop and transfer the technologies to the needy countries. This situation provides an opportunity for countries to strengthen production and export capabilities in the area of low-carbon goods. Trade in low-carbon goods not only facilitates the use of low-carbon goods in the importing countries to protect the environment, but also stimulates the use and production of low-carbon goods within the country of export too (Mmieh et al., 2012; and Kalirajan and Anbumozhi, 2014). Therefore, trade in low-carbon goods to achieve NDCs is a more effective approach to facilitate delinking economic development from environmental degradation.

In this context, a more important and specific question is to find out a country's potential of low-carbon goods export and the constraints to achieve its potential. Using China as a case study, this paper aims to address the following issues concerning: (1) Identifying a list of low-carbon goods; (2) Ranking the identified low-carbon goods by their ability to reduce CO2 emissions and by the difficulties in producing them in China; (3) Evaluating China's low-carbon goods exports performance in terms of the trade scale, the export structure, efficiency, and the market distribution over the recent years.

It is generally believed that China through its access to advanced technology can

take a lead role in the production and trade of renewable and low emissions energy products. This opportunity has recently been boosted by the institution of individual country nationally determined contributions (NDCs) under the Paris Agreement in 2015. This in turn has increased the demand particularly from the Asian countries for low carbon and renewable energy products. The question arises whether China has taken advantage of these developments in terms of enhancing its low carbon energy product exports. The importance of this research not only lies in providing relevant policy implications for China in terms of a more efficient low-carbon goods export scheme through analysing its export potential and constraints, but also facilitating China to reach its ambitious promise to abate CO2 emission under the Paris Agreement.

2. A LIST OF LOW-CARBON GOODS

Low-carbon goods are similar to environmental goods that prevent, minimise, limit, and correct environmental damage (Steenblik, 2005). Low-carbon goods can be referred to products that emit nearly no greenhouse gases. When doing empirical research on low-carbon goods, many scholars have used environmental friendly goods as proxies for low-carbon goods, as there are no solid non-controversial low-carbon goods lists (Nguyen and Kalirajan, 2016). To ensure the accuracy of this research, it is necessary to derive a list of low-carbon goods. Drawing on Van Niekerk et al. (2014), low-carbon goods list is prepared from the existing lists of environmental goods lists. The popular six existing environmental goods lists are: The World Trade Organization (WTO) 153 list, the World Bank list, the International Centre for Trade and Sustainable Development (ICTSD) list, the Fondation pour des idées sur le développement (FERDI) list, the Asia-Pacific Economic Cooperation (APEC) 54 list, and the Organisation for Economic Co-operation and Development (OECD) list.

2.1. The WTO List

The WTO compiled a list of products that have been submitted by its members and regarded the 153 environmental friendly products in 12 sub-groups that submitted in the Doha negotiations as a comprehensive list called 'the Friends' 153 List' comprising 9 friends: Canada, the US, Norway, Switzerland, the EU, New-Zealand, Japan, Korea, and Taiwan, China (Sugathan, 2013). This list was the result of the downsizing of a previous list earlier submitted by the 9 Friends which exceeded 400 products (Sugathan, 2013).

International Institute for Sustainable Development (IISD) analysed the WTO 153 environmental goods' potential for greenhouse gases emission reductions and concluded only 30 products in the Renewable Energy Plant sub-heading possessed the high potential. Therefore, this research includes those 30 products first and has searched other products that should be verified as low-carbon goods from the remaining environmental lists.

2.2. The World Bank List

The WTO compiled a list of products that have been submitted by its members and regarded the 153 environmental friendly products in 12 sub-groups that submitted in the Doha negotiations as a comprehensive list called 'the Friends' 153 List' comprising 9 friends: Canada, the US, Norway, Switzerland, the EU, New-Zealand, Japan, Korea, and Taiwan, China (Sugathan, 2013). This list was the result of the downsizing of a previous list earlier submitted by the 9 Friends which exceeded 400 products (Sugathan, 2013).

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2.3. The ICTSD List

The ICTSD list complied in 2012 is the most recent one submitted by the ICTSD (Van Niekerk et al., 2014). The list categorised totally 63 environmental goods into three parts: (1) Renewable Products and Energy Sources; (2) Environmental Monitoring, Analysing and Assessment Equipment; (3) Waste Management, Recycling and Remediation. Among the three sub-groups, this research verifies all 38 environmental goods in Renewable Products and Energy Sources category as low-carbon goods, including 24 overlapping ones in the WTO list. HS 853931 (Discharge lamps, fluorescent, hot cathode) was dropped, as it is more of an energy source rather than the renewable energy, which has limited potential for low-carbon emission (Van Niekerk et al., 2014). Totally, 13 new low-carbon goods from this list were added.[1]

2.4. The FERDI List

Australia, Colombia, Hong Kong, China, Norway, and Singapore drew a 26 'core list' in 2011 from the WTO's combined 411 code list, serving as a starting point for WTO negotiations as there is a limited overlap between different countries' lists (Balineau and Jaime, 2013). There are 14 goods that belong to the Renewable Energy sub-heading, among which 13 overlap with the low-carbon goods verified by the WTO 153 list. The newly added low-carbon product from this list is HS 841950.

[1] They are HS 732111, HS 732190, HS 841012, HS 841221, HS 841229, HS 841950, HS 850610, HS 850630, HS 850640, HS 850650, HS 850660, HS 850680, and HS 850690.

2.5. The APEC List

APEC is the first to single out environmental goods as a category for the purpose of trade liberalization (Sugathan, 2013; Vossenaar, 2013). 21 Asia-Pacific economies agreed in 2012 to lower applied tariffs on a set of 54 different environmental goods, classified into three categories: (1) Pollution Management; (2) Cleaner Technologies and Products; (3) Resources Management Group. This research selected 8 goods in Renewable Energy Plant that belongs to the Resources Management Group, including 4 new products that do not appear on one of the above cited lists.[2]

2.6. The OECD List

This list is illustrated based on the definition of the environment industry and is developed for analytical rather than trade negotiations purposes such as the APEC list. This research included all the 15 low-carbon goods grouped under the Renewable Energy Plant but they all overlap with products selected from the above lists.

To sum up, we have included 30 products that have been verified by IISD for greenhouse gases emission reduction purposes from the WTO list, 13 products from Renewable Products and Energy Sources category in the ICTSD list, HS 841950 from the FERDI list, and 4 products from Resources Management Group in the APEC list. Total number of 48 low-carbon goods was selected for the empirical analysis and all low-carbon goods can be found from Appendix Table A1.

3. CHINA'S LOW-CARBON GOODS: THE RANKING

Based on the selected 48 low-carbon goods list, this section ranks China's low-carbon goods based on the following two criteria:

(1) The ability to reduce low-carbon emission. This criterion is based on the consensus of different low-carbon lists. A score of 1 will be given based on its appearance in each of the following six lists: WTO, WB, ICTSD, FERDI, APEC, and OECD, so the total score out of 6 will be allocated for a good that appears in all 6 lists.

(2) China's ability to produce those goods, using the Revealed Comparative Advantage (RCA_i):

$$RCA_i = \frac{X_{i,CHN.}/X_{CHN.}}{X_{i,t}/X_t},$$

[2] The 4 new low-carbon products are HS 841012, HS 841013, HS 841381, and HS 841911.

where i is the specific low-carbon goods, $X_{CHN.}$ is China's total exports, and X_t represents the total world exports. The RCA indicates whether a country proportionately export more of one product related to its exports compared with other countries do, representing a proxy for its production ability. To calculate the scores of this exercise and ensure the normal distribution of scores, the following methodology to quantify the scores was used and the same total score out of 6 was given:

$$Score_i = \begin{cases} 6 & if\ RCA_i \geq RCA_{max} \\ 0 & if\ RCA_i \leq RCA_{min} \\ \frac{CRA_i - RCA_{min}}{RCA_{max} - RCA_{min}} & if\ RCA_{min} \leq RCA_i \leq RCA_{max} \end{cases}.$$

The final ranking of China' low-carbon goods that contribute to carbon emissions reduction was calculated by multiplying the scores in each criterion to favour those goods with similar scores for all two criteria (See Appendix Table A1 for the whole list with scores). Table 1 shows the top 5 low-carbon goods for China in terms of the total scores and scores in each band. They are: photosensitive semiconductor (HS854140), parts of hydraulic turbines (HS841090), hydraulic turbine of power between 1.000 kW and 10.000 kW (HS841012), lead acid accumulators (HS850720), and optical fibres and optical fibre bundles (HS900190). This ranking helps the Chinese government understand its potential and constraints on low-carbon goods export in terms of the production ability and carbon emissions reduction ability of each product, which creates the policy implication of concentrating on the production of relatively more important low-carbon goods.

Table 1. Top 5 Low-carbon Goods with Scores

HS Code	Description	Score1	Score2	Total
854140	Photosensitive semiconductor devices, incl. photovoltaic cells	6	3.05	18.30
841090	Parts of hydraulic turbines and water wheels incl. regulators	5	2.20	11.02
841012	Hydraulic turbines and water wheels, of a power > 1.000 kW but <= 10.000 kW	4	2.72	10.88
850720	Lead acid accumulators (excluding spent and starter batteries)	3	2.62	7.89
900190	Lenses, prisms, mirrors and other optical elements, of any material, unmounted	3	1.92	5.75

4. CHINA'S LOW-CARBON GOODS EXPORTS PERFORMANCE

This section gauges China's low-carbon goods exports performance in terms of its trade scale, export structure, and market distribution.

4.1. The Trade Scale

China's low-carbon goods export volume experienced a huge increase from 2006 to

2015 (Figure 1). In 2006, China's low-carbon goods export volume was US $19.51 billion, but in 2015 the figure reached US $73.16 billion, nearly 4 times growth within the recent 10 years. However, the world Financial Crisis in 2008 hit China's low-carbon goods exports to some extent and the export volume decreased by 11% from $39.72 billion in 2008 to $35.35 billion in 2009, before which the annual growth rate kept at around 43%, above the world-level (Figure 2). After the world Financial Crisis, the exports saw a 64.81% increase in 2010 and afterwards the growth rate kept positive despite in 2012 when the world exports of low-carbon goods decreased slightly (Figure 3).

Table 2. The Proportion of Different Low-carbon Products (%)

HS Code	Description*	2006	2008	2010	2012	2015
732111	Plate warmers for gas and other fuels, of steel	2.97	1.98	2.29	2.68	2.89
732190	Domestic appliances; non-electric	1.36	0.74	0.52	0.70	0.86
841381	Pumps and liquid elevators	2.31	0.93	0.56	0.77	0.42
841581	Air conditioning machines	1.55	0.90	0.98	1.01	1.06
841861	Heat pumps	4.71	0.59	0.30	0.26	0.24
848340	Gears and gearing	1.74	1.89	1.65	2.75	3.03
850300	Electric motors and generators	4.83	4.60	4.27	6.24	5.45
850440	Electrical static converters	35.22	26.27	22.02	25.98	24.34
850610	Cells and batteries	6.25	3.66	2.66	2.88	2.42
850720	Electric accumulators	4.79	4.31	2.56	2.89	3.43
853710	Boards, panels, consoles,	3.78	4.75	4.46	6.44	7.78
854140	Electrical apparatus; photosensitive	12.61	29.57	43.02	29.21	31.21
900190	Optical elements; lenses	3.38	2.51	2.18	3.11	2.91
900290	Optical elements	2.26	0.62	0.39	0.43	0.54
903289	Regulating or controlling	1.65	2.26	2.07	2.43	2.60

Note: *See Table A1 in the Appendix for detailed descriptions.

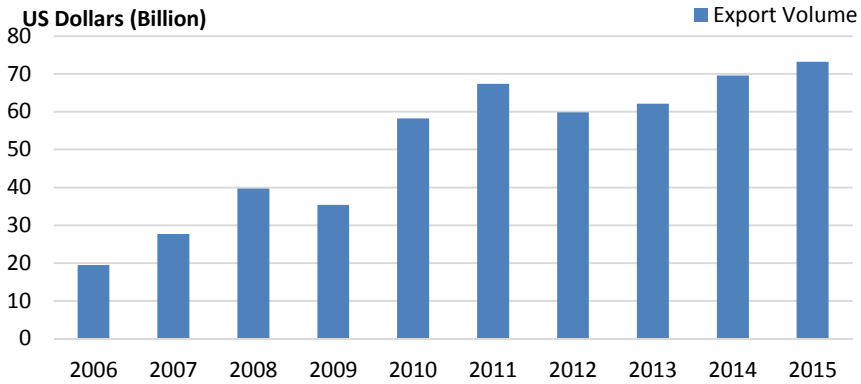

Figure 1. China's Export Volume of Low-carbon Goods (2006-2015)

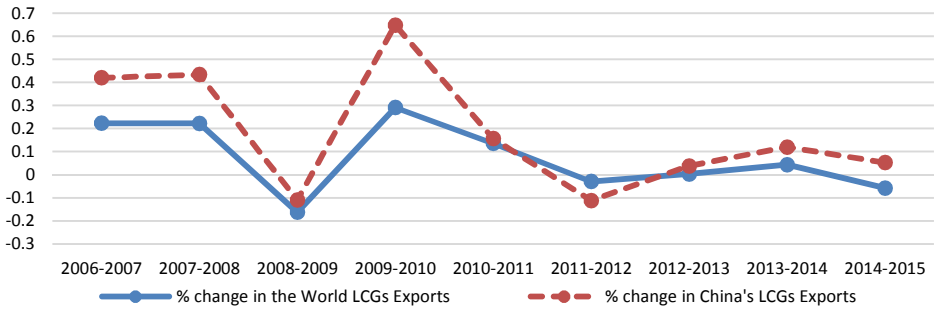

Figure 2. China and the World Low-carbon Goods Exports: Percentage Changes

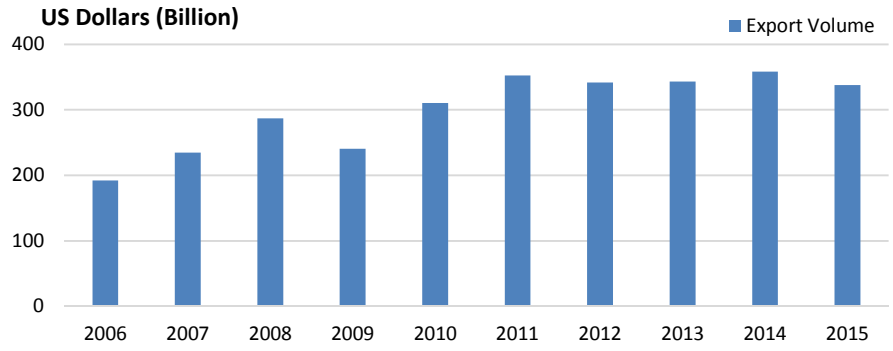

Figure 3. The World Export Volume of Low-carbon Goods (2006-2015)

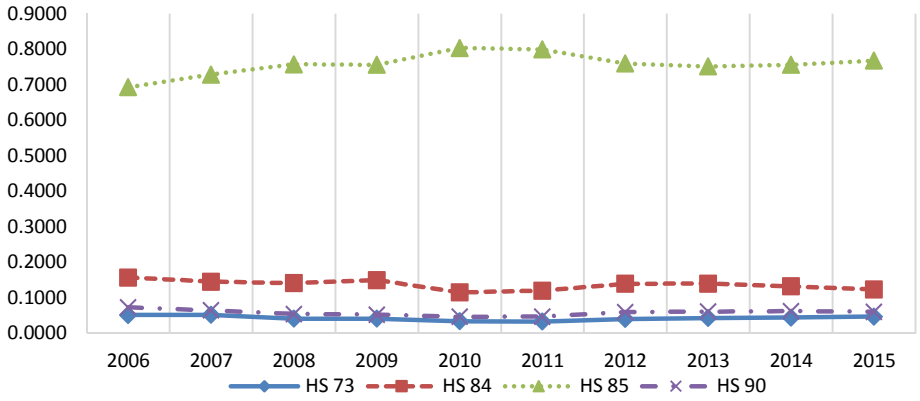

Figure 4. Low-carbon Categories Exported to the World

Overall, China's low-carbon goods exports performed well and most of the time, its growth rate had been above the world level. Although China's export performance is easily influenced by the world trade environment, in 2015, China's low-carbon goods exports kept increasing despite the gloomy world economic environment with the world GDP declining from $78.09 trillion to $73.50 trillion.

4.2. The Export Structure

From Figure 4, we can see that China's low-carbon goods export structure has been stable since 2006. China's low-carbon good exports mainly consisted of electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles (HS 85) and machinery, mechanical appliances, nuclear reactors, boilers; parts thereof (HS 84).

Above 70% of the total exports volume is from the HS 85 group, among which HS 850440 consisted of around one third. HS 850440 also accounted for around a quarter of China's total low-carbon goods exports (Table 2). The exports of the HS 84 group decreased from 15.67% in 2006 to 12.37% in 2015, but it remained as the second largest low-carbon goods exports category. Among HS 84, the proportion of HS 848340 in total low-carbon exports saw an increasing trend from 1.74% to 3.03%, becoming the main exports in its category, while the figure for HS 841861 decreased from 4.71% to 0.24%. The HS 90 group and Articles of iron or steel (HS 73) only accounted for about 5% of total exports. HS732111 and HS900190 were the main export products from those two categories respectively.

Table 3. The Proportion of China's Low-carbon Goods Exports to Main Countries (Regions) (%)

Continents	Countries	2006	2008	2010	2012	2015
Asia	Japan	12.61	7.90	5.21	7.54	10.54
	South Korea	4.92	4.77	2.76	3.88	4.03
	Singapore	2.32	1.61	1.06	1.37	2.82
	India	3.11	4.35	3.75	3.84	4.12
	Philippine	0.57	0.40	0.33	0.50	1.40
	Vietnam	0.75	1.21	1.44	1.44	2.04
	Thailand	1.18	0.95	0.85	1.87	2.24
	Laos	0.05	0.08	0.02	0.09	0.16
	Malaysia	1.62	1.14	0.96	1.39	1.65
	HK, China	16.97	11.97	12.14	13.41	15.88
	Macao, China	0.20	0.12	0.03	0.04	0.11
Europe	Germany	7.84	10.45	14.85	5.60	2.93
	United Kingdom	1.27	0.99	0.87	1.38	1.95
	Italy	1.88	2.43	9.31	2.49	1.22
	Netherland	1.98	2.78	7.65	8.43	2.59
	France	1.11	1.36	1.92	1.33	1.09
	Spain	2.32	11.06	1.54	0.93	0.67
America	The USA	15.37	12.15	11.77	15.40	15.99
	Canada	0.95	0.66	0.80	0.89	0.80
	Mexico	0.95	1.08	0.83	1.17	1.35
	Brazil	0.89	1.19	1.05	1.57	1.14
	Argentina	0.23	0.17	0.15	0.27	0.25
Others	Australia	1.32	1.09	2.26	2.46	1.91
	Russia	0.83	0.98	0.64	1.02	0.85
	Egypt	0.19	0.20	0.20	0.20	0.31

Source: Compiled by the authors with date from UN Comtrade.

4.3. The Market Distribution

China's low-carbon goods were mainly exported to Japan, HK-China, and the USA. Table 3 shows that the USA has been China's largest export destination and it accounted for 15.99% of the total low-carbon goods exports in 2015, followed by HK-China (15.88%), and Japan (10.54%). Europe as a whole has been the second largest continent importing low-carbon goods from China, with the average proportion of around 22%. Another interesting observation from Table 3 is that China has changed its markets from European developed countries to developing countries in Asia and America recently. For example, the proportion of China's low-carbon goods exports to Germany and Spain dropped from 7.84% and 2.32% in 2006 to 2.93% and 0.67% in 2015 respectively. On the other hand, India, Philippines, Vietnam, Mexico, and Brazil have become China's important low-carbon goods trading partners.

5. DETERMINANTS OF CHINA'S LOW-CARBON GOODS EXPORTS

The next important question examined in this study concerns the identification of the determinants of China's low-carbon goods exports growth over the recent years. Exports growth has been analysed in the literature with different methodologies, among which the Constant Market Share (CMS) approach is a frequently used one. Logically, it is argued that a country's exports may grow faster than the world average export growth because of any one or combination of the following reasons: (i) correct selection of the exporting commodities, for which the demand has been growing steadily; (ii) correct identification of the region, which enjoy consistent high growth; and (iii) following the best practice production techniques to beat the competitors (Ahmadi, 2006). The CMS analysis is designed through its decomposition approach to help the policymakers better understand the relative importance of the above cited drivers of export growth.

The CMS approach to explain export growth was introduced by Tyszynski in 1951. Since then, many researchers including Leamer and Stern (1970), Richardson (1971a, b), and Jepma (1986) popularised this approach with a few modifications. The first modification established by Leamer and Stern (1970) was criticised by Richardson (1971a, b) by indicating that the level of product or market disaggregation can change the value of the above mentioned effects. Though Jepma's improved version overcomes the above cited limitations and brings dynamic factors, it failed to interpret each effect in the model (Ahmadi, 2006). The discussion of each effect is important from the policy perspective. The empirical research focus in this study is on China's 48 low-carbon goods exports to its 25 trading partners, who consumed about 80% of China's total exports of low-carbon goods during the period of analysis. Drawing on Leamer and Stern (1970), it is assumed that a country' export share (r) in the world market remains constant over a one-year period, which can be decomposed into the world trade effect, the product composition effect, the market distribution effect, and the competitiveness

effect over the ten years to gauge the determinants of China's low-carbon goods export growth.

5.1. The CMS Model

The model at each level is discussed as follows in this section:

5.1.1. The First-level Analysis

In this analysis, exports are consumed as a single good for China. Changes in the low-carbon goods can be written:

$$\Delta X = X^2 - X^1 = rX^1 + (X^2 - X^1 - rX^1), \quad (1)$$

where X^2 represents the value of China's low-carbon goods exports in period 2. X^1 is the exports value in period 1. The above identity (1) means that export growth from period 1 to period 2 $(X^2 - X^1)$ can be divided into components associated with a general increase in world exports (rX^1) and the competitiveness effect, which is measured as a residual $(X^2 - X^1 - rX^1)$.

5.1.2. The Second-level Analysis

In this analysis, exports are considered for a diverse set of low-carbon goods to a market as the consumption of single commodity goods does not exist. For the i th good, the change in exports between two periods may be written as follows:

$$\Delta X_i = X_i^2 - X_i^1 = r_i \times X_i^1 + (X_i^2 - X_i^1 - r_i \times X_i^1), \quad (2)$$

where X_i^2 and X_i^1 represent the value of China's exports of low-carbon goods (i) in the period 2 and 1 individually. r_i is the percentage of changes in the world exports of i during the period from 2 to 1.

Applying summation to aggregate the export, (2) gets:

$$\Delta X = X^2 - X^1 = \sum r_i \times X_i^1 + \sum\left(X_i^2 - X_i^1 - r_i \times X_i^1\right),$$

$$\Delta X = X^2 - X^1 = \sum[r \times X_i^1 + (r_i - r)X_i^1] + \sum(X_i^2 - X_i^1 - r_i \times X_i^2),$$

$$\Delta X = X^2 - X^1 = (r \times X_i^1) + \sum[(r_i - r)X_i^1] + \sum(X_i^2 - X_i^1 - r_i \times X_i^2). \quad (3)$$

The above identity indicates that a country's export is decomposed into (a) the general rise in world exports: $r \times X_i^1$, (b) the commodity composition effect of the exporting country in period 1: $\sum[(r_i - r)X_i^1]$, and (c) the competitiveness effect:

$\sum(X_i^2 - X_i^1 - r_i \times X_i^2)$ that is measured as a residual showing the difference between actual export increase and the hypothetical increase had the exporting country maintained its share of export of each commodity group.

The commodity composition effect, $\sum[(r_i - r)X_i^1]$ would be positive, when China concentrates on the export of low-carbon goods in which the market for the good is growing relatively faster than the total world export growth. The commodity composition effect, $\sum[(r_i - r)X_i^1]$ would be negative, when China concentrates on the export of low-carbon goods in which the market for the good is growing relatively slower than the total world export growth. The residual stands for export competitiveness.

5.1.3. The Third-level Analysis

Similar with the diversification of commodities for exports, there are also many international markets that China exporting to. So in the third-level analysis, the assumption of a single market is relaxed. That is to say, the change in exports of i th good to country (region) j can be written as:

$$\Delta X_{i,j} = X_{i,j}^2 - X_{i,j}^1,$$

$$\Delta X_{i,j} = r_{i,j} \times X_{i,j}^1 + (X_{i,j}^2 - X_{i,j}^1 - r_{i,j} \times X_{i,j}^1), \tag{4}$$

where $r_{i,j}$ is the world export of goods i to country (region) j. $X_{i,j}$ is the value of China's low-carbon goods exports to country (region) j.

Applying summation to aggregate the export, (4) becomes:

$$\Delta \mathrm{X} = X^2 - X^1 = \sum\sum r_{i,j} \times X_{i,j}^1 + \sum\sum(X_{i,j}^2 - X_{i,j}^1 - r_{i,j} \times X_{i,j}^1),$$

$$\Delta X = X^2 - X^1 = \sum\sum r * X_{i,j}^1 - r \times X_{i,j}^1 + r_i * X_{i,j}^1 - r_i * X_{i,j}^1 + r_{i,j} \times X_{i,j}^1 + \sum\sum(X_{i,j}^2 - X_{i,j}^1 - r_{i,j} \times X_{i,j}^1),$$

$$\Delta X = X^2 - X^1 = \sum\sum\left(r \times X_{i,j}^1\right) + \sum\sum(r_i - r)X_{i,j}^1 + \sum\sum\left(r_{i,j} - r_i\right)X_{i,j}^1 + \sum\sum(X_{i,j}^2 - X_{i,j}^1 - r_{i,j} \times X_{i,j}^1),$$

$$\Delta X = X^2 - X^1 = \sum r \times X_i^1 + \sum(r_i - r)X_i^1 + \sum\sum\left(r_{i,j} - r_i\right)X_{i,j}^1 + \sum\sum(X_{i,j}^2 - X_{i,j}^1 - r_{i,j} \times X_{i,j}^1),$$

$$\Delta X = X^2 - X^1 = r \times X_i + \sum(r_i - r)X_i^1 + \sum\sum\left(r_{i,j} - r_i\right)X_{i,j}^1 + \sum\sum(X_{i,j}^2 - X_{i,j}^1 - r_{i,j} \times X_{i,j}^1). \tag{5}$$

The above identity (5) shows that export growth can be decomposed into (a) the

general rise in world export or the world effect: $r \times X_i$; (b) the commodity composition effect $\sum[(r_i - r)X_i^1]$; (c) the market distribution of the exporting country's exports $\sum\sum(r_{i,j} - r_i)X_{i,j}^1)$; and (d) the competitiveness effect that is measured as a residual indicating the differences between actual export increase and the hypothetical increase when the exporting country had maintained its share of export of each commodity group to each country or region (Thanh and Nguyen, 2011).

The market distribution effect, $\sum\sum(r_{i,j} - r_i)X_{i,j}^1$ would be positive when China concentrates its exports of low-carbon goods on the market that have faster-growing demands for goods i. The market distribution effect, $\sum\sum(r_{i,j} - r_i)X_{i,j}^1$ would be negative when China concentrates its exports more in the stagnant country or region of the world.

5.2. Data

Data for the empirical analysis is taken at the HS 6-digit level from the Commodity Trade Statistics Database (COMTRADE, http://comtrade.un.org/data) and the Trade Map in the International Trade Centre (ITC, http://www.trademap.org). The COMTRADE provides data on China's export volume of different low-carbon goods (HS 6-digit level) to different countries (regions) and to the whole world, while the Trade Map provides data on the world low-carbon goods (HS 6-digit level) export volume to each country (regions) during the period from 2006 to 2015.

5.3. Empirical Results

China's low-carbon goods export growth from 2006 to 2015 was divided into the world trade effect, the product composition effect, the market distribution effect, and the competitiveness effect by using the third-level analysis, assuming that a country' export share (r) was constant over a one-year period. The contribution of each of the above effects to China's low-carbon goods export growth from 2006 to 2015 is discussed in the following sections.

5.3.1. The World Trade Effect

The world trade effect refers to the amount of low-carbon goods export growth due to the overall world export growth, assuming that the market share is stable. Figure 5 shows that the world trade effect helped China's low-carbon goods exports, especially during 2009-2010 and 2010-2011 when the world was recovering from the World Financial Crisis. The world trade effect contributed $10.28 billion and $7.94 billion respectively during the above periods. During 2011-2012 and 2014-2015, the world trade effect exerted a negative effect on China's exports and the 2014-2015 negative effect was partially due to the decline in the world GDP. Overall, the world trade environment was good during the period of 2006 to 2011, bringing on average about

$2.13 billion growth annually for China's low-carbon goods exports. However, since 2012, this effect diminished, indicating other sources for export growth are needed. Trade policy reforms such as trade agreements with more trading partners is a potential way (Kalirajan et al., 2019).

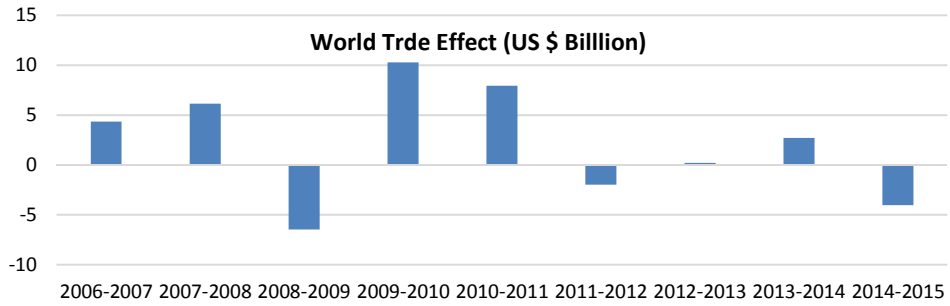

Figure 5. The World Tarde Effect Trends

5.3.2 The Commodity Composition Effect

The Commodity Composition Effect indicates whether a country concentrates on goods that have faster-growing demands compared with others. The analysis shows that China's low-carbon goods commodity composition effect fluctuated and the overall effect over the past 10 years was very limited at around -$0.016 billion (Figure 6). During 2009 to 2010, China changed its commodity composition and the commodity composition effect reached the highest value of $4.91 billion. However, it reached the lowest value of -$5.26 billion in 2011-2012. Since then, the commodity composition effect had limited influence except for the last year (2014-2015), when the positive effect bounced back to the value of $2.20 billion.

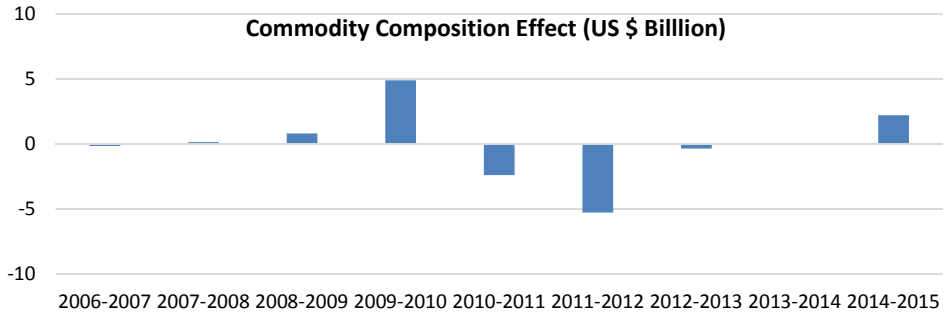

Figure 6. The Commodity Composition Effect Trends

5.3.3. The Market Distribution Effect

The Market Distribution Effect shows whether a country concentrates on exporting goods i to the market that have faster-growing demands for i. Figure 7 shows that the market distribution effect for China's low-carbon goods exports was all positive except from 2008 to 2009, during which time the global financial crisis hindered China's low-carbon goods exports to the USA, the United Kingdom, and Japan (Table 3). During 2009 to 2010, the market distribution effect reached its highest value of $9.58 billion. However, the growth of market distribution effect showed a slightly declining trend in the following years until the growth recovered a little bit after 2013. It is also worth noting that during the period from 2011 to 2013, China changed its markets from the European developed countries to developing countries in Asia and America. In the long run, this strategy might help China's low-carbon goods export growth through improving its market distribution effect as new economies now have higher potentials and demands for low-carbon goods with their growing level of environmental awareness.

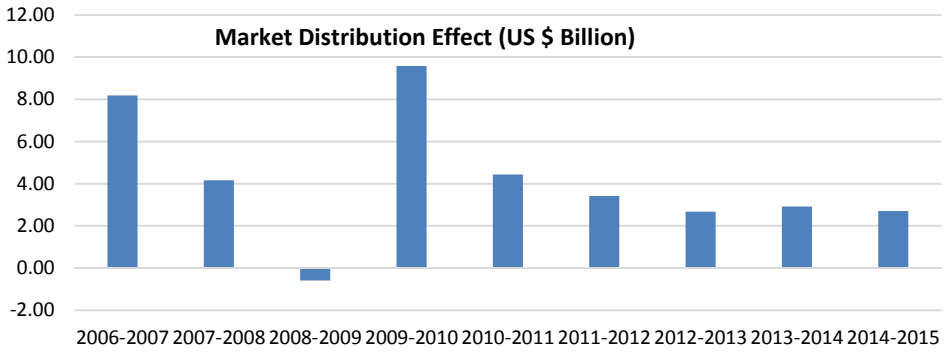

Figure 7. The Market Distribution Effect Trends

5.3.4. The Competitiveness Effect

The results of the competitiveness effect are shown in Figure 8, which indicates that this effect on China's low-carbon goods export growth mostly remained negative with the lowest value of -$4.18 billion during 2006-2007. Nevertheless, the effect showed an increasing trend in the following two years until 2009-2010. From 2010, negative contribution of the competitiveness effect continued, except for the time during 2013-2014. The rising exchange rate could be a possible cause for the low competitiveness as the low-carbon goods have now become relatively more expensive for China's trading partners. For example, the USA, Japan, Germany, and Hong Kong-China accounted for around 50% of China's low-carbon goods exports, but the

foreign exchange rate per CNY (Chinses Yuan) in those four countries had shown increasing trends during the study period (Appendix Table 3). Apart from considering the appreciation of the RMB, it is more important for China to encourage innovation and develop low-cost low-carbon goods through investing on research and development (RandD) to catch up with its competitors.

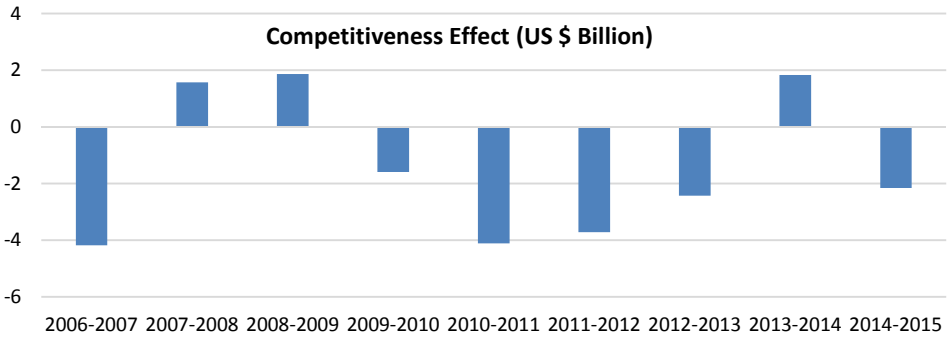

Figure 8. The Competitiveness Effect Trends

6. CONCLUSIONS AND POLICY IMPLICATIONS

In conclusion, among the above four effects, the world trade effect and the market distribution effect exerted significant positive influence on China's low-carbon good export growth with the average annual value of $2.13 billion and $4.16 billion respectively during the period of analysis of 2006-2015. However, from the trade policy perspective, it is worth noting that the competitiveness effect had constrained China's low-carbon goods export growth and the commodity composition effect also had limited influence.

In the context of the commodity composition effect, electrical static converters (HS 850440), and electrical apparatus; photosensitive (HS 854140), in which China has revealed its comparative advantage (Table 1), both showed significant export growth rates during the study period. These two categories accounted for more than 50% of the total low-carbons exports of China (Table 2). However, if China wanted to enjoy significant positive commodity composition effect, then it needs to pay attention to one of the world highest export growth low-carbon goods-HS 841012 that China has comparative advantage (Table 1 and Appendix Table A2). Further, it is time for China to diversify its low-carbon commodity composition to include the top 3 world highest export growth commodities, such as HS 841013, HS 730820, and HS 841869 (Appendix Table A2). Such a diversification has the potential to stimulate China's low-carbon export growth as well.

The market distribution effect of China's low-carbon goods export is always positive

except during 2008-2009. The empirical results indicate that the primary engine for China's low-carbon goods export growth had been the market distribution effect during the study period. It appears that the good performance is correlated with China's new exporting strategies of changing its markets from the European developed countries to the developing countries in Asia and America. This change has the potential to increase China's low-carbon goods exports because of the possibility of those countries using low-carbon goods to achieve their Nationally Determined Contributions (NDCs).

It is alarming to note the negative low-carbon goods competitiveness effect, which had reduced the value of export by $1.44 billion annually on average during the period of analysis. The implication is that China's low-carbon goods appear to be not competitive enough compared with the exports from other countries. It is imperative for China to encourage more innovation through research and development (RandD) to develop low-cost low-carbon goods to catch up with the competitor countries. The rising exchange rate could also be a possible cause for the low competitiveness as the low-carbon goods have now become relatively more expensive for China's trading partners.

APPENDIX

Table A1. Low-carbon Goods List with Scores

HS Code	Description	Score
854140	Electrical apparatus; photosensitive, including photovoltaic cells, whether or not assembled in modules or made up into panels, light emitting diodes	18.299
841090	Turbines; parts of hydraulic turbines and water wheels, including regulators	11.019
841012	Turbines; hydraulic turbines and water wheels, of a power exceeding 1000kW but not exceeding 10000kW	8.158
850720	Electric accumulators; lead-acid, (other than for starting piston engines), including separators, whether or not rectangular (including square)	7.859
900190	Optical elements; lenses n.e.c. in heading no. 9001, prisms, mirrors and other optical elements, unmounted, of any material (excluding elements of glass not optically worked)	5.748
850440	Electrical static converters	5.662
850300	Electric motors and generators; parts suitable for use solely or principally with the machines of heading no. 8501 or 8502	5.045
841581	Air conditioning machines; containing a motor driven fan, other than window or wall types, incorporating a refrigerating unit and a valve for reversal of the cooling/heat cycle (reversible heat pumps)	4.910
841911	Heaters; instantaneous gas water heaters, for domestic or other purposes	4.878
730820	Iron or steel; structures and parts thereof, towers and lattice masts	4.584
850610	Cells and batteries; primary, manganese dioxide	3.846
848360	Clutches and shaft couplings (including universal joints)	3.441
900290	Optical elements; n.e.c. in heading no. 9002 (e.g. prisms and mirrors), mounted, being parts or fittings for instruments or apparatus, of any material (excluding elements of glass not optically worked)	3.289
732111	Cooking appliances and plate warmers; for gas fuel or for both gas and other fuels, of iron or steel	3.244
848340	Gears and gearing; (not toothed wheels, chain sprockets and other transmission elements presented separately); ball or roller screws; gear boxes and other speed changers, including torque converters	3.243

Table A1. Low-carbon Goods List with Scores (Cont')

HS Code	Description	Score
840690	Turbines; parts of steam and other vapour turbines	3.106
850161	Generators; AC generators, (alternators), of an output not exceeding 75kVA	3.099
732190	Domestic appliances; non-electric, parts thereof, of iron or steel	2.892
841011	Turbines; hydraulic turbines and water wheels, of a power not exceeding 1000kW	2.781
841919	Heaters; instantaneous or storage water heaters, non-electric, other than instantaneous gas water heaters	2.631
853710	Boards, panels, consoles, desks and other bases; for electric control or the distribution of electricity, (other than switching apparatus of heading no. 8517), for a voltage not exceeding 1000 volts	2.619
840682	Turbines; steam and other vapour turbines, (for other than marine propulsion), of an output not exceeding 40MW	2.426
850231	Electric generating sets; wind-powered, (excluding those with spark-ignition or compression-ignition internal combustion piston engines)	2.172
840681	Turbines; steam and other vapour turbines, (for other than marine propulsion), of an output exceeding 40MW	2.121
850162	Electric generators; AC generators, (alternators), of an output exceeding 75kVA but not exceeding 375kVA	2.034
841013	Turbines; hydraulic turbines and water wheels, of a power exceeding 10000kW	1.841
841861	Heat pumps; other than air conditioning machines of heading no. 8415	1.806
850164	Electric generators; AC generators, (alternators), of an output exceeding 750kVA	1.794
850163	Electric generators; AC generators, (alternators), of an output exceeding 375kVA but not exceeding 750kVA	1.712
841869	Refrigerating or freezing equipment; n.e.c. in heading no. 8418	1.384
841221	Engines; hydraulic power engines and motors, linear acting (cylinders)	1.291
841990	Machinery, plant and laboratory equipment; parts of equipment for treating materials by a process involving a change of temperature	1.180
841229	Engines; hydraulic power engines and motors, other than linear acting (cylinders)	1.027
850690	Cells and batteries; primary, parts thereof	1.015
850640	Cells and batteries; primary, silver oxide	0.894
841381	Pumps and liquid elevators; n.e.c. in heading no. 8413	0.746
903289	Regulating or controlling instruments and apparatus; automatic, other than hydraulic or pneumatic	0.699
850650	Cells and batteries; primary, lithium	0.680
841950	Heat exchange units; not used for domestic purposes	0.908
761100	Aluminium; reservoirs, tanks, vats and similar containers, for material (not compressed or liquefied gas), of a capacity over 300l, whether or not lined, not fitted with mechanical/thermal equipment	0.219
850660	Cells and batteries; primary, air-zinc	0.218
850239	Electric generating sets; (excluding those with spark-ignition or compression-ignition internal combustion piston engines), other than wind powered	0.198
290511	Alcohols; saturated monohydric, methanol (methyl alcohol)	0.104
841182	Turbines; gas-turbines (excluding turbo-jets and turbo-propellers), of a power exceeding 5000kW	0.075
850630	Cells and batteries; primary, mercuric oxide	0.047
220710	Indentured ethyl alcohol; of an alcoholic strength by volume of 80% vol. or higher	0.023
841181	Turbines; gas-turbines (excluding turbo-jets and turbo-propellers), of a power not exceeding 5000kW	0.022
850680	Cells and batteries; primary, (other than manganese dioxide, mercuric oxide, silver oxide, lithium or air-zinc)	0.000

Table A2. The Top 15 Commodity with the Highest World Exports Annual Growth (%)

HS Code	Description	Growth rate
854140	Electrical apparatus; photosensitive, including photovoltaic cells, whether or not assembled in modules or made up into panels, light emitting diodes	17.01
841013	Turbines; hydraulic turbines and water wheels, of a power exceeding 10000kW	15.72
730820	Iron or steel; structures and parts thereof, towers and lattice masts	14.21
841869	Refrigerating or freezing equipment; n.e.c. in heading no. 8418	13.98
841012	Turbines; hydraulic turbines and water wheels, of a power exceeding 1000kW but not exceeding 10000kW	13.89
850231	Electric generating sets; wind-powered, (excluding those with spark-ignition or compression-ignition internal combustion piston engines)	11.93
850640	Cells and batteries; primary, silver oxide	11.83
841011	Turbines; hydraulic turbines and water wheels, of a power not exceeding 1000kW	11.57
850720	Electric accumulators; lead-acid, (other than for starting piston engines), including separators, whether or not rectangular (including square)	10.69
841221	Engines; hydraulic power engines and motors, linear acting (cylinders)	9.71
853710	Boards, panels, consoles, desks and other bases; for electric control or the distribution of electricity, (other than switching apparatus of heading no. 8517), for a voltage not exceeding 1000 volts	9.69
290511	Alcohols; saturated monohydric, methanol (methyl alcohol)	9.51
850650	Cells and batteries; primary, lithium	9.08
220710	Indentured ethyl alcohol; of an alcoholic strength by volume of 80% vol. or higher	8.59
850440	Electrical static converters	8.47

Table A3. Exchange Rate per CNY

	USA	Japan	Germany	HK-China
2006	0.125	14.586	0.100	0.974
2007	0.131	15.479	0.096	1.025
2008	0.144	14.875	0.098	1.121
2009	0.146	13.697	0.105	1.135
2010	0.148	12.965	0.112	1.148
2011	0.155	12.351	0.111	1.205
2012	0.158	12.640	0.123	1.229
2013	0.161	15.752	0.122	1.252
2014	0.163	17.245	0.123	1.262
2015	0.161	19.437	0.145	1.245

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