International Journal of Economics and Finance; Vol. 7, No. 2; 2015
ISSN 1916-971X E-ISSN 1916-9728
Published by Canadian Center of Science and Education

CO_2 Emission Embodied in International Trade: Evidence for China

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Received: November 6, 2014 Accepted: December 3, 2014 Online Published: January 25, 2015

doi:10.5539/ijef.v7n2p138 URL: http://dx.doi.org/10.5539/ijef.v7n2p138

Abstract

As the biggest developing country, China generate huge amount of CO_2 emissions. Some studies suggest that export trade is an important contributor to this, and China has been the pollution haven for the developed countries. A few developed countries also treat this as an excuse to take measures to punish China. This study calculates the amount of CO_2 emissions of 18 exporting industries in China using the data from 2001 to 2010. The findings reveal that the amount of CO_2 emissions is the result of export volume multiplying carbon emission per unit export. Carbon emission per unit export is dropping year by year, as the total amount of CO_2 emissions is rising year by year. As a result, the major contributor to huge amount of CO_2 emissions in export is the increasing volume of export inducing by abroad consumption. Empirical study also reveals that China has not been the pollution haven for developed countries.

Keywords: CO_2 emission amount, CO_2 emission intensity, export trade, pollution haven effect

1. Introduction

From last century, as the rapid growing in developed and developing countries, the dependence on fossil energy induces rising emission of carbon dioxide and other greenhouse gases. The rising emission of carbon dioxide leads to the environmental pollution, climate warming and ecology unbalance, and has been a constraint to economic and social sustainable development. In this case, it becomes urgent for every country to find a green development mode that could improve atmospheric environment without hurt economic efficiency. With the term of "Low Carbon Economy" was first raised in England in 2003, many countries set off a "Low Carbon Revolution". In the post-crisis era, some countries treat low carbon economy as an important economic growth point, and apply multiple measures to regulate carbon dioxide emission.

As the biggest developing country, China generate huge amount of CO_2 emissions. According to the IEA, the total amount of CO_2 emissions caused by fossil fuel in China (including Hong Kong) was about 0.8 billion tons in 1971. By 2011, the emissions increased to about 8 billion tons, which accounted for 25% of the total amount in the whole world. Some studies suggest that export trade is an important contributor to this, such as Shui and Harriss (2006), as well as Peter and Hertwich (2008). Researches in Elliott (2010), Fowlie (2009) and Glen (2008) reveal that regional carbon regulation in developed countries will cause emission intensive industries shifting to developing countries where are called pollution haven, such as China. The shifting will induce developing countries to increase emissions, which was known as 'carbon leakage'.

The amount of CO_2 emissions in export trade is the result of export volume multiplying carbon emission intensity, which is carbon emission per unit export. Even Carbon emission intensity is dropping year by year in China, the total amount of CO_2 emissions is rising yearly. As a result, the major contributor to huge amount of CO_2 emissions of export in China is the increasing export volume inducing by abroad consumption. China and the importers should jointly afford the responsibility, and it is not properly for the developed country take punitive measures to China. This research firstly applies the input-output (I-O) analysis to calculate the direct and indirect CO_2 emissions intensity for 18 industries in China. On this basis, this paper measures the CO_2 emissions level for 18 export industries from 2001 to 2010. Finally, it tests the pollution haven effect and carbon leakage effect by measuring the net exports as a proportion of consumption (NETXC).

2. Literature Review

I-O analysis is usually used to measure CO_2 emissions embodied in international trade. There are two kinds of I-O frameworks: one is the single regional I-O framework, such as researches in Machado (2001), Munksgaard and Pedersen (2001) and Mongelli (2006). The other is multiregional I-O framework, such as Shui & Harriss (2006) examine the influence of US-China trade on CO_2 emissions. They find that about 7%–14% of CO_2 emissions in China are the result of producing exports for US consumers. Peters & Hertwich (2008) measures CO_2 emissions embodied in the trade among 87 regions in 2001, finding that the CO_2 emissions embodied in China export trade accounts for 24% of the total emissions volume in China, while the CO_2 emissions embodies in import trade only accounts for 7%.

Most of researchers in China also use the I-O analysis to measure the CO_2 emissions embodied in trade, such as Qi Ye (2008) , Zhang Xiaoping (2009) and Sun Xiaoyu (2009). Their researches suggest that the rapid growth in China's export trade is at the cost of huge energy consumption and CO_2 emissions.

There is a technical problem when calculating CO_2 emissions: how to measure the CO_2 emissions embodied in processing trade? The importing parts of processing trade generate emissions before importing from abroad. It will overvalue the total amount of CO_2 emissions embodied in China's export trade if we do not eliminate these parts. Chen Ying (2008) and Wei Benyong (2009) solve this problem by revising the I-O analysis. Excepting the I-O framework, some researchers also measure the CO_2 emissions by other analysis. Zhou Nianli (2007) testes the level of sustainable development in China's export trade from 1985–2003 by grey cluster model. His research reveals that the economic benefits of export are obtained at the cost of environment deterioration and resource depletion. Liu Qiang (2008) uses the Life Cycle Assessment method to calculate the embodied energy and carbon emission in 46 kinds of export products, and finds that the huge energy consumption and carbon emission are against to the sustainable development of China.

3. Model and Data Description

3.1 Model Description

Indirect CO_2 emission amount is the total volume of CO_2 emissions generated in the entire product chain, and it reflects more complete emission behavior in every industry compared to the direct CO_2 emission amount. I-O analysis is usually used to measure the indirect CO_2 emission amount. We can establish the input and output relationship among economic sectors:

$$AX + Y = X \tag{1}$$

Where X is the total output, A is the direct consumption coefficient matrix $(a_{ij})_{n\times n}$, $a_{ij} = x_{ij} / X_j (i, j = 1, 2, ..., n)$ is called direct consumption coefficient, and represents the outputs of sector i required as input by sector j to produce one unit of its monetary output. The AX means the share of final output consumed as intermediate input. If we deduct AX from X, we can get final output Y, which is:

$$X = (I - A)^{-1} Y \tag{2}$$

Where $(I\text{-}A)^{-1}$ is called Leontief inverse matrix.

CO_2 emissions are mainly generated from the consumption of fossil energy. According to the IPCC Guidelines for national greenhouse Gas Inventories 2006, the equation to calculate direct CO_2 emission is:

$$C_i = \sum_{allfuels} Consumption_{fule} \times \alpha_{fule} \tag{3}$$

Where C_i is the direct CO_2 emission amount in sector i, and $Consumption_{fuel}$ is the sum of energy consumed in this sector. The measuring units of various energies are converted into standard coal. α_{fuel} is the CO_2 emission coefficient of each energy, it can be calculated according to the equation given by volume 2 of the IPCC Guidelines for National Greenhouse Gas Inventories. Energies of this paper referred are as following: crude coal, coke, crude oil, fuel oil, gasoline, kerosene and natural gas.

The direct emission intensity is:

$$CM_i = C_i / X_i \tag{4}$$

Where X_i is represented by the added value of output in each sector. If we multiply CO_2 emission intensity by Leontief inverse matrix $(I\text{-}A)^{-1}$, the indirect CO_2 emission intensity can be received:

$$TCM_i = CM_i (I - A)^{-1} \tag{5}$$

The indirect CO_2 emission amount embodied in export for sector i is:

$$ETC_i = CM_i (I - A)^{-1} EX_i \tag{6}$$

Where EX_i is the export volume in sector i.

The total amount of indirect CO_2 emission embodied in export for all export sectors is:

$$ETC = \sum_{i=1}^{n} CM_i (I - A)^{-1} EX_i \tag{7}$$

In an open economy, the intermediate inputs are not only produced domestically, but also imported from abroad. The imported has already generated CO_2 emissions before importing. If we do not eliminate this part, it will overvalue the total amount of CO_2 emissions embodied in China's export, so *A* here only refer to the intermediate inputs produced domestically.

3.2 Date Description

Input-output table (I-O table): In order to eliminate the importing inputs of Leontief inverse matrix, this paper adopts the I-O table supplied by OECD database. The research period is from 2001 to 2010. Now, the OECD database only provide1995, 2000 and 2005 I-O table. Since the production technique do not change dramatically, this study uses price index to revise I-O relationship for 18 sectors on the basis of 2000 and 2005 I-O table.

Sectors: the 18 exporting sectors are as following: sector 1.Agriculture, hunting, forestry & fishing; sector 2.Mining & quarrying; sector 3.Food products, beverages & tobacco; sector 4.Textiles, textile products, leather & footwear; sector 5.Wood & wood products; sector 6.Pulp, paper, paper product, printing; sector 7.Coke, refined petroleum products & nuclear fuel; sector 8.Chemicals excluding pharmaceuticals; sector 9.Rubber & plastics products; sector10.Other non-metallic mineral products; sector 11.Non-ferrous metal & ferrous metal smelting & rolling processing industry; sector 12.Fabricated metal products; sector13.Machinery & equipment; sector14.Office, accounting & computing machinery; sector15.Electrical machinery & apparatus; sector 16.Radio, television & communication equipment; sector 17.Motor vehicles, trailers & semi-trailers; sector 8.Other manufacturing.

Other data source: the data of various energy consumption and industrial added value are from China Statistical yearbook.

4. Empirical Study

4.1 Indirect CO_2 Emission Intensity for Various Sectors

According to the above model, we calculate the indirect CO_2 emission intensity for every sector from 2001 to 2010, and the details are shown by table 1. In general, the indirect CO_2 emission intensities for most sectors are declining year by year. The differences among various sectors are very big. We can classify the 18 export sectors into three categories: high emission sector which annual average emission intensity is above 0.1, medium emission sector which annual average is between 0.06 and 0.1, low emission sector which annual average is below 0.06.

Table 1. Indirect CO_2 emission intensity (billion tons/100 billion RMB) for 18 sectors (2001–2010)

sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
1	0.050	0.047	0.040	0.034	0.027	0.025	0.020	0.018	0.017	0.016	0.035
2	0.143	0.139	0.130	0.074	0.075	0.063	0.052	0.053	0.058	0.050	0.100
3	0.064	0.056	0.049	0.039	0.038	0.033	0.027	0.026	0.025	0.023	0.045
4	0.075	0.067	0.057	0.050	0.051	0.045	0.037	0.036	0.034	0.031	0.057
5	0.095	0.087	0.076	0.062	0.061	0.053	0.042	0.042	0.040	0.036	0.070
6	0.110	0.100	0.087	0.081	0.090	0.081	0.066	0.065	0.063	0.057	0.093
7	0.277	0.264	0.226	0.210	0.183	0.167	0.130	0.130	0.138	0.132	0.216
8	0.237	0.217	0.179	0.142	0.140	0.123	0.099	0.100	0.092	0.080	0.168
9	0.109	0.098	0.084	0.070	0.079	0.069	0.055	0.056	0.056	0.051	0.085
10	0.290	0.262	0.239	0.229	0.189	0.152	0.119	0.129	0.120	0.102	0.216
11	0.421	0.406	0.333	0.252	0.232	0.205	0.168	0.159	0.157	0.152	0.297
12	0.198	0.189	0.157	0.120	0.113	0.100	0.081	0.078	0.077	0.073	0.141
13	0.153	0.143	0.119	0.093	0.092	0.082	0.066	0.064	0.063	0.059	0.111
14	0.054	0.050	0.042	0.032	0.041	0.036	0.029	0.029	0.029	0.026	0.043
15	0.132	0.124	0.104	0.083	0.068	0.060	0.049	0.048	0.047	0.043	0.093
16	0.063	0.059	0.050	0.040	0.037	0.032	0.026	0.026	0.025	0.023	0.045
17	0.113	0.104	0.086	0.071	0.080	0.070	0.056	0.055	0.054	0.050	0.087
18	0.175	0.111	0.091	0.082	0.064	0.055	0.043	0.042	0.040	0.036	0.094

4.2 CO_2 Emission Amount Embodied in China's Export

We can also calculate the annual indirect CO_2 emission amount embodied in every export sector as shown in table 2. Firstly, the indirect CO_2 emission amounts embodied in most export sectors are rising yearly, but there are also several sectors reveal an opposite tendency, such as the Mining & quarrying (sector 2). According to chapter 4.1, the indirect CO_2 emission intensities of most sectors are declining, so the main reason that cause CO_2 emission amounts rising are the increasing export amounts. Secondly, the differences among sectors are very big. In some sectors, such as the chemicals excluding pharmaceuticals (sector 8), Non-ferrous metal & ferrous metal smelting & rolling processing industry (sector 11), Machinery & equipment (sector 131), the annual indirect CO_2 emissions embodied in export are above 200 million tons. These sectors with big growth rate are the main sources of the rising indirect CO_2 emissions embodied in China's export. In general, the total amount of indirect CO_2 emission embodied in China's export is also rising year by year, while the indirect CO_2 emission amount declined in 2008 and 2009 due to the world financial crisis.

Table 2. Indirect CO_2 emission amount embodied in China's export (million tons)

sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	19.8	22.7	24.7	18.3	17.4	15.4	14.7	12.3	12.7	14.3
2	65.9	62.2	65.6	44.7	61.0	46.5	35.0	46.2	27.1	26.3
3	54.5	51.1	48.2	44.4	50.3	50.2	46.7	48.6	51.0	43.7
4	46.8	48.2	51.5	54.1	67.7	74.9	73.1	78.3	67.4	76.0
5	14.0	14.5	14.0	12.4	12.6	10.8	8.6	8.4	8.9	12.8
6	19.8	21.3	24.4	27.0	39.4	45.8	52.8	53.7	48.6	53.4
7	79.9	83.3	109.9	149.1	145.1	135.2	132.9	196.7	134.5	184.6
8	267.8	284.2	302.3	324.9	428.8	446.0	485.0	585.1	411.7	495.2
9	70.1	75.5	79.6	89.8	132.8	140.8	130.8	136.3	122.5	146.4
10	112.0	126.1	145.3	187.2	206.0	208.1	183.3	222.5	182.2	203.0
11	233.3	246.5	289.7	490.2	585.2	844.5	921.1	1023.0	391.4	602.3
12	36.7	41.1	44.6	58.1	71.2	92.2	100.8	119.7	65.8	90.2
13	211.4	251.8	290.1	319.9	408.8	465.8	551.5	609.8	489.1	587.9
14	4.6	4.8	5.6	6.3	11.9	13.0	12.1	14.1	12.4	15.0
15	183.4	206.2	220.2	229.7	236.2	265.3	270.1	296.5	241.4	303.9
16	163.4	207.9	244.5	302.1	371.7	418.8	388.1	398.4	351.2	408.7
17	89.3	92.6	112.5	127.2	192.2	222.8	245.5	281.3	230.3	313.6
18	32.8	26.9	26.8	30.2	30.5	31.8	30.9	36.1	30.0	33.3
Total	1705	1867	2099.5	2515.7	3068.8	3528.0	3683.1	4167.1	2877.9	3610.6

4.3 Empirical Test of the Pollution Haven Effect

Even from 1990s some papers have mentioned that the strict environment policy in developed country may induce pollution industries shifting to developing country, there are few empirical studies to test. Janicke (1997) uses the NETXC, which is the ratio of net exports to domestic consumption, to judge the influence of environment policy to the pollution industry in developed country. The study of Janicke (1997) only focuses on pollution industry. Cole (2004) improves the NETXC, adds the clean industry as sample, and tests the pollution haven effect in developing country. On the basis of Cole's study, this paper adopts the following NETXC to test whether the strengthening of carbon policy in developed country make China to be the pollution haven of carbon emission:

$$NETXC_{it} = \frac{X_{it}^{A} - M_{it}^{A}}{C_{it}} = \frac{X_{it}^{A} - M_{it}^{A}}{P_{it} - X_{it}^{W} + M_{it}^{W}} \tag{8}$$

Where $i = 1, 2......n$ indicates sector 1, sector 2, …, sector n, t indicates year. $NETXC_{it}$ is the NETXC for sector i in a given year. X_{it}^{A} represents the export amount of sector i in China to Annex I countries in a given year. Annex I countries refer to the contracting parties mentioned in the Annex I of UNFCC (United Nations Framework Convention on Climate Change). Most of the parties are developed countries. M_{it}^{A} represents the import amount of sector i in China from Annex I countries in a given year. The balance between X_{it}^{A} and M_{it}^{A} indicates the net export amount of sector i in China to Annex I countries. C_{it} represents the net consumption of sector i in China, it equals the production (indicated as P_{it}) minus the export to other countries, then plus the import (indicated as M_{it}^{W}) from all over the world in sector i (indicated as X_{it}^{W}). The data for import and export are selected from the OECD database, and the amount of production refers to the output added value.

Through the NETXC, We can decide the influence of Annex I parties strengthening carbon policy on the level of CO_2 emission in China. If the NETXC in some sector is rising year by year, it means that the relative strict carbon policy in Annex I parties cause China getting advantage in that sector. If the sector is high-emission intensive, it will induce CO_2 emission rising and carbon leakage. This paper calculates the NETXC for 18 exporting sectors from 2001 to 2010, as seen in table 3.

For high emission sectors, the NETXC for some are roughly rising yearly, such as the Chemicals excluding pharmaceuticals (sector 8) and the Machinery & equipment (sector 13), but the NETXC for Coke, refined petroleum products & nuclear fuel (sector 7) reveals an inverse trend, while the Non-ferrous metal & ferrous metal smelting & rolling processing industry (sector 10) shows an inverted-U shape. It indicates that the relative strict carbon policy in developed country do not obviously enhance China's advantages in high emission sectors. For medium emission sectors, the NETXC for Mining & quarrying (sector 2) and other manufacturing (sector 18) reveals an increasing trend, while sector 6 shows inversely. The rest three sectors in this group do not reveal simple increasing or declining trend. For the low emission sectors, only the NETXC for Radio, television & communication equipment (sector 16) increase year by year, the rest sectors reveal inverse trend except sector 14.

Table 3. The NETXC for 18 exporting sectors (2001–2010)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
High emission sectors										
sector7	-0.111	-0.079	-0.074	-0.061	-0.109	-0.153	-0.123	-0.178	-0.130	-0.151
sector8	-0.268	-0.272	-0.265	-0.267	-0.243	-0.216	-0.199	-0.170	-0.164	-0.163
sector10	0.137	0.179	0.168	0.164	0.224	0.222	0.181	0.160	0.106	0.113
sector11	-0.199	-0.195	-0.184	-0.112	-0.096	-0.015	0.011	0.057	-0.081	-0.053
sector12	1.433	2.160	2.307	2.554	9.780	10.37	5.711	4.331	0.721	0.781
sector13	-0.383	-0.379	-0.398	-0.374	-0.256	-0.184	0.016	0.016	-0.045	-0.100
Medium emission sectors										
sector2	0.014	-0.007	-0.018	-0.050	-0.059	-0.065	-0.073	-0.082	-0.096	-0.117
sector6	-0.219	-0.194	-0.173	-0.157	-0.117	-0.088	-0.064	-0.055	-0.047	-0.060
sector9	0.503	0.538	0.449	0.412	0.608	0.569	0.454	0.372	0.224	0.212
sector15	0.120	0.138	0.088	0.046	0.122	0.162	0.223	0.246	0.096	0.153
sector17	-0.228	-0.212	-0.227	-0.176	-0.108	-0.175	-0.096	-0.074	-0.140	-0.204
sector18	-0.783	-0.868	-0.915	-0.915	-0.921	-0.931	-0.971	-0.969	-1.049	-0.961
Low emission sectors										
sector1	-0.007	-0.004	-0.008	-0.026	-0.020	-0.020	-0.019	-0.025	-0.025	-0.028
sector3	0.137	0.117	0.099	0.087	0.093	0.092	0.067	0.047	0.039	0.030
sector4	-1.587	-1.424	-1.292	-1.421	-1.482	-1.404	-1.598	-1.877	-3.465	-2.470
sector5	0.635	0.753	0.796	0.762	0.850	0.856	0.535	0.334	0.181	0.150
sector14	-1.036	-0.933	-1.021	-1.005	-1.004	-0.973	-0.957	-1.013	-1.064	-1.014
sector16	-0.194	-0.075	-0.050	0.038	0.118	0.132	0.135	0.231	0.179	0.236

5. Conclusion

This paper calculates the CO_2 emissions embodied in China's export trade from 2001 to 2010 by the input-output framework. Result reveals that the major contributor to huge amount of CO_2 emissions of export in China is the increasing export volume inducing by abroad consumption, not the CO_2 emissions intensity which declining yearly. This paper also use NEXTC to test the effect of relative strict policy in developed country on China's high emission sectors, medium emission sectors and low emission sectors, and finds the changes of trade advantages in each group are not consistent, which means carbon leakage do not occur and China do not become the pollution haven of CO_2 emissions for developed country. CO_2 emission is a global public pollution source, it needs all countries enhance cooperation, rationally allocate and consciously fulfill emission reduction obligations, improve the cooperation framework under the Kyoto Protocol, as well as look for the cooperation framework for post-Kyoto protocol.

Acknowledgement

Supported by Research on carbon policy influencing China's export advantages-from the perspective of green TFP (13SQR008), Shandong Normal University Young Teacher Research Project (Humanities and Social Sciences Category).

Reference

Chen, Y., Pan, J., & Xie, L. (2008). Energy Embodied in Goods of International Trade in China: Calculation and Policy Implications. *Economics Research, 7*, 11–25.

Copeland, B. R., & Taylor, M. S. (2003). *Trade and the Environment: Theory and Evidence*. Princeton: Princeton University Press.

Elliott, J., & Foster, I. (2010). Trade and Carbon Taxes. *American Economic Review: Papers & Proceedings,100*(2), 465–469. http://dx.doi.org/10.1257/aer.100.2.465

Fowlie, M. L. (2009). Incomplete Environmental Regulation, Imperfect Competition, and Emissions Leakage. *American Economic Journal: Economic Policy, 1*, 72–112. Retrieved from http://www.aeaweb.org/articles.php?doi=10.1257/pol.1.2.72

Glen, P., & Edgar, G. H. (2008). CO_2 Embodied in International Trade with Implications for Global Climate Policy. *Environmental Science & Technology, 42*, 1401–1407. http://dx.doi.org/10.1021/es072023k

Janicke, M., Binder, M., & Monch, H. (1997). 'Dirty Industry': Patterns of Change in Industrial Countries. *Environmental and Resource Economics, 9*, 467–491. http:// www.dx.doi.org/10.1007/BF02441762

Liu, Q., Zhuang, X., Jiang, K., & Han, W. (2008). Energy and Carbon Embodied in Main Exporting Goods of China. *China Industrial Economics, 8*, 46–55.

Machado, G. R., & Worrell, E. (2001). Energy and Carbon Embodied in the International Trade of Brazil: an Input-Output Approach. *Ecological Economics, 39*, 409–424. http://dx.doi.org/10.1016/S0921-8009(01)00230-0

Mongelli, I., Tassielli, G., & Notarnicola, B. (2006). Global Warming Agreements, International Trade and Energy Carbon Embodiments: an Input-Output Approach to the Italian Case. *Energy Policy, 34*, 88–100. http://dx.dio.org/10.1016/j.enpol.2004.06.004

Munksgaard, J., & Pedersen, K. A. (2001). CO_2 Accounts for Open Economies: Producer of Consumer Responsibility? *Energy Policy, 29*, 327–334. http://dx.dio.org/10.1016/S0301-4215(00)00120-8

Peters, G. P., & Hertwich, E. G. (2008). CO_2 Embodied in International Trade with Implications for Global Climate Policy. *Environmental Science & Technology, 42*, 1401–1407. http://dx.dio.org/10.1021/es072023k

Qi, Y., Li, H., & Xu, M. (2008). Accounting Embodied Carbon in Import and Export in China. *China Population, Resources and Environment, 3*, 8–13.

Shui, B., & Harriss, R. C. (2006). The Role of CO_2 Embodiment in US-China Trade. *Energy Policy, 34*, 4063–4068. http://dx.doi.org/10.1016/j.enpol.2005.09.010

Sun, X., & Zhang, X. (2009). Empirical Analysis on the Energy Consumption Effect and the Environment Effect of China's Export Trade: Based on Hybrid-units IO Model. *The Journal of Quantitative & Technical Economics, 4*, 33–44.

Wei, B. et al. (2009). Estimation of Carbon Emissions Embodied in International Trade for China: An Input-Output Analysis. *Journal of Beijing Normal University (Nature Science), 8*, 413–419.

Zhang, X. (2009). Carbon Dioxide Emissions Embodied in China's Foreign Trade. *Acta Geographica Sinica, 64*, 234–242.

Zhou, N. (2007). Export Sustainable Development: Theoretic Meaning, Evaluation Model and Empirical Research. *China Population, Resources and Environment, 17*, 38–43.