The Carbon Reduction Effect of the Trade of Paper Products in China

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Abstract Through using the data of import and export trading of China's paper products in 2012, we utilize the method of volume source biomass equation and net primary productivity (NPP) to calculate the carbon reduction effect of papermaking raw materials trade, and utilize the method of IPCC guidelines for inventories to calculate the carbon emission effect of paper and paper products trade. The results show that the distinctive characteristics of China's paper products trade has resulted in the dual effects on the domestic carbon emissions. On the one hand, large imports of paper-making raw materials make China reduce domestic forest felling, with the effect of carbon emission reduction. On the other hand, net exports of paper and paper products increase the domestic carbon emissions, with the effect of carbon emission. The carbon emission reduction effect of China's paper-making raw materials trade is obvious and up to 19.0211 million tons. This is equal to the total volume of 180.5709 million cubic meters forest's annual carbon sequestration. The carbon emission effect of paper and paper products trade is only 0.5136 million tons, which is not significant compared with the former. In general, China's paper product trade causes the significant effect on carbon emission reduction.

Key words Trade of paper products, Carbon emission, Carbon emission effect

1 Introduction

In recent years, with the continuous development of China's papermaking industry, there have been more and more studies on the papermaking industry. At present, paper and paper products have become the main wood forest products for export in China, second only to furniture. The international trade of paper products has bidirectional effect on the carbon emission in China. On the one hand, voluminous imported wood pulp, waste paper and other raw materials have reduced the demand for domestic timber, thereby reducing the amount of harvesting of domestic forests, increasing forest carbon sinks and indirectly reducing emissions of carbon dioxide; on the other hand, paper, paperboard, paper products other manufactured goods will release large amounts of carbon dioxide during the production and processing, and the increasing export volume will increase domestic emissions of carbon dioxide. Domestic studies on the trade and carbon emission are mostly the overall analyses at the level of country[1-2], and there are also some researches on the trade and carbon emission concerning the specific industry, such as the use of panel data of China's industrial sector to analyze the carbon emission effect of export trade[3], and the use of input-output analysis to assess the hidden carbon emission in the import and export of China's agricultural products[4]. However, there are few studies on the carbon emission of trade of paper products. Therefore, using the relevant data on China's papermaking industry in 2012, this paper first converts the net imports of pulp into wood consumption and thus forest stock volume, and employs the volume-derived biomass equations and net primary productivity (NPP) method to calculate the decrement of carbon emission. Then based on the energy consumption of China's papermaking industry, this paper uses IPCC inventory guidelines to calculate the increased carbon emissions arising from the Chinese net exports of paper and paper products. Finally, according to the calculation results, this paper gets the specific value of influence of trade of paper products on China's carbon emissions, in order to verify whether the trade of paper products has carbon reduction effect.

Received: January 26, 2014 Accepted: March 1, 2015

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2 China's trade of paper products and its influence on China's carbon emissions

2.1 China's trade of paper products China is a major producer of paper in the world, and both the production and consumption of paper products rank first in the world. In 2012, the total production of paper pulp was 78.67 million t in China, and the total consumption of paper pulp was 93.48 million t. The production and consumption of paper products significantly increased. The production was 48.04 million t, an increase of 6.43% over 2011, and the consumption was 45.73 million t, an increase of 6.65% over 2011. The trade of paper products in China can be divided into two categories: trade of papermaking raw materials and paper product trade[5]. In terms of papermaking raw materials, the import volume of paper pulp and waste paper was 16.47 million t and 30.07 million t in 2012, respectively, with a significant increase, while the export volume of paper pulp and waste paper was 79900 t and 2400 t, respectively, with a significant decrease. Compared with the import and export trade of papermaking raw materials, the paper product trade shows different characteristics. In 2012, the import volume of paper and paperboard was only 3.11 million t, and the export volume of paper products was 0.14 million t, showing significant negative growth, while the export volume of paper and paperboard, and paper products was

5.13 million t and 2.45 million t, respectively, with an increase over 2011. The import and export volume of paper pulp, waste paper, paper and paperboard is shown in Fig. 1. The total import and export volume of papermaking raw materials in China was 46.6223 million t, while the total import and export volume of paper and paper products was only 10.83 million t, less than a quarter of the former. The net import of papermaking raw materials has carbon reduction effect and the net export of paper and paper products has carbon emission effect, so it can be roughly inferred that the trade of paper products in China may have the carbon reduction effect.

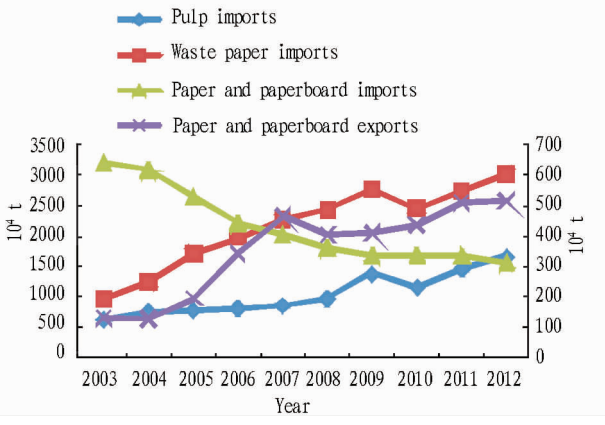

Fig. 1 The import and export volume of paper pulp, waste paper, paper and paperboard

2.2 The path of influence of paper product trade on China's carbon emission The flow process of import and export trade of paper products in China is shown in Fig. 2, and since this process contains the carbon emission, it can be used for analyzing the path of carbon emission. Path I: The papermaking raw materials produced at home $\xrightarrow{\text{processed and manufactured}}$ paper and paper products consumed at home. The paper products are not only manufactured and processed, but also consumed at home, so there is no increase or decrease in domestic carbon emission due to trade.

Path II: The papermaking raw materials produced at home $\longrightarrow$ to be directly exported. The papermaking raw materials produced at home are exported directly, and the felling of timber for papermaking is at home, so this path reduces the number of domestic forest, thereby reducing the forest carbon sequestration and increasing the domestic carbon emissions. Path III: The papermaking raw materials produced at home $\xrightarrow{\text{processed and manufactured}}$ paper and paper products for export. The papermaking raw materials are from domestic production and the processed paper and paper products are exported to meet foreign consumption, so this path increases the domestic carbon emissions. Path IV: The imported papermaking raw materials $\xrightarrow{\text{processed and manufactured}}$ paper and paper products for export. Only the processing of papermaking raw materials is carried out at home, so this path also increases the domestic carbon emissions, but the increased carbon emissions are from the processing and manufacturing process at home. Path V: The imported papermaking raw materials $\xrightarrow{\text{processed and manufactured}}$ paper and paper products consumed at home. The papermaking raw materials are from imported from abroad, and the processed paper and paper products are used to meet domestic consumption, so this path reduces the domestic carbon emissions and the reduced carbon emissions are from the saved timber for papermaking at home. Path VI: The paper and paper products directly imported $\longrightarrow$ meet domestic consumption. The felling of papermaking timber as well as processing and manufacturing of paper and paper products is conducted abroad, so this path reduces the domestic carbon emissions. Through the analysis, it can be found that compared with the closed conditions, Path I does not affect the total domestic carbon emissions; Path II, III and IV will increase the domestic carbon emissions; Path V and VI are conducive to the reduction of domestic carbon emissions. The combined effects of paper product trade on domestic carbon emissions depend on the import and export of papermaking raw materials and paper products. Therefore, there is a need to perform checking and calculation from the two perspectives in order to study the carbon reduction effect of paper product trade in China.

3 Analysis of carbon reduction effect of trade of papermaking raw materials in China

3.1 Data selection and research methods China is a net importer of papermaking raw materials, so the import and export of papermaking raw materials make China save a certain amount of wood for pulping, which indirectly increases China's forest stock volume and forest carbon sinks, with carbon reduction effect. Starting from this idea, we select the relevant data from Chinese Paper Industry Annual Report (2012), to examine the carbon reduction effect of trade of papermaking raw materials in China in 2012.

3.1.1 The paper pulp supply saved at home. Assuming there is no import and export trade of paper products in China (namely the whole industry needs to achieve self-sufficiency in accordance with the present consumption), it is calculated based on this standard: The paper pulp supply saved in China = paper pulp imports − paper pulp exports − pulp consumption for exported paper and paper products + converted amount of pulp for the imported paper and paper products = net imports of paper pulp − net pulp consumption for exported paper and paper products. The trade of papermaking raw materials has saved China's paper pulp supply at about 36.11418 million t. They are mainly from the imported pulp and waste paper. Given that the imported pulp in 2012 is all wood pulp and the imported waste paper has been converted, so the domestic paper pulp saved can be approximately replaced by wood pulp.

3.1.2 The corresponding amount of wood for the paper pulp saved. Different pulping methods will lead to different yields, and there are also differences in the raw timber materials consumed. The pulp yield rate of chemical pulping, semi-chemical pulping,

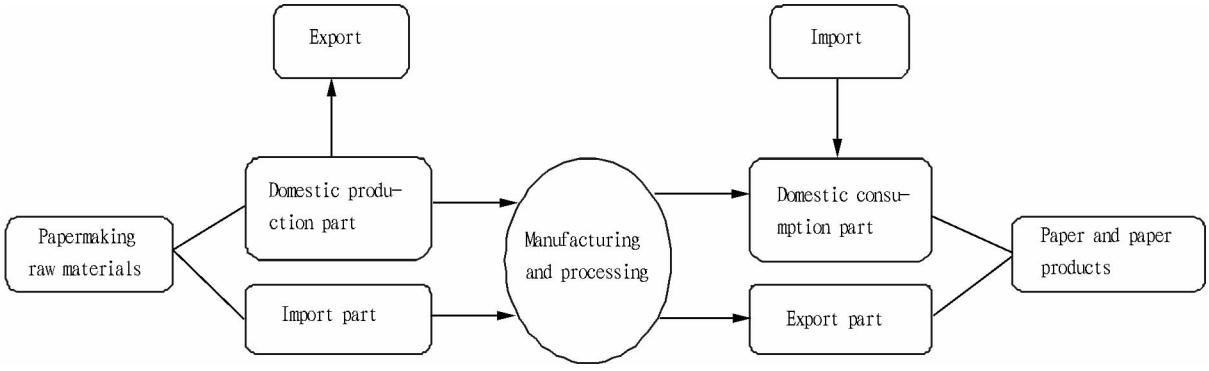

Fig. 2 The flow process of trade of paper products in China

chemical mechanical pulping and mechanical pulping methods is 40% – 50%, 65% – 84%, 85% – 94% and 94% – 98%, respectively, and chemical pulping method has the highest pulp yield rate[6]. The main component of paper pulp is cellulose and usually the wood cellulose content is about 50% (mass ratio)[7], so the pulp yield rate is selected as 50%. Based on the known pulp yield rate, we can calculate the wood consumption that corresponds to paper pulp amount as follows: The corresponding wood consumption = paper pulp amount ÷ 0.5 = 72.22836 million t. According to the relevant data selected from wood density tables recommended by IPCC, the average density of common tree varieties for China's papermaking is calculated at about 0.5 t/m^3. Thus the mass of wood consumed can be converted into volume, namely the timber volume = timber mass ÷ 0.5 = 144.45672 million m^3. Based on the conversion relationship between timber volume and stock volume (timber volume = stock volume × percentage of out-turn (generally 60% to 80%), the percentage of out-turn is taken at 0.8 and the corresponding total volume of timber is 180.5709 million m^3.

Table 1 The import and export of paper pulp, waste paper, paper and paper products in China in 2012 Unit: 10^4 t

	Paper pulp	Waste paper	Paper and paperboard	Paper products
Imports	1647	3007	311	14
Exports	7.99	0.24	513	245

Note: The paper pulp imported in 2012 is all wood pulp.

3.1.3 The indirectly increased forest carbon sink. NPP (Net Primary Productivity) is used to calculate the annual average carbon sequestration of trees. NPP can explain the net fixed amount of CO_2 absorbed by vegetation from the atmosphere, so indirectly increased forest carbon sink is obtained using NPP multiplied by factor of 0.5[8]. There is a certain function relationship between NPP and biomass, and biomass can be obtained by volume-derived biomass equations, so this paper uses this function relationship to estimate the NPP. Because of different tree species, the specific calculation formula is also different, so this paper chooses four kinds of timber most commonly used for papermaking in China (redpine, larch, eucalyptus and poplar) to calculate the indirectly increased forest carbon sinks for different tree species, respectively. The estimation equations of biomass and NPP of common tree species for papermaking in China are shown in Table 2.

Table 2 Equations used to calculate biomass and NPP of China's common tree species for papermaking

Tree species	Biomass estimation equations	R^2	P	NPP estimation equations	R^2	P	References
Redpine	$B = 0.5101V + 1.0451$	0.92	$P < 0.01$	$NPP = B/(0.238A + 0.0304B)$	0.83	$P < 0.001$	[9],[10]
Larch	$B = 0.6096V + 33.806$	0.82	$P < 0.01$	$NPP = B/(0.179A + 0.0529B)$	0.66	$P < 0.001$	[9],[10]
Eucalyptus	$B = 0.8873V + 4.5539$	0.80	$P < 0.01$	$NPP = 0.208B + 1.836$	0.94	$P < 0.01$	[9]
Poplar	$B = 0.4754V + 30.6034$	0.87	$P < 0.01$	$NPP = B/(0.205A + 0.0695B)$	0.30	$P < 0.001$	[9],[10]

Note: B is biomass (t/ha); V is the stock volume (m^3/ha); NPP is Net Primary Productivity (t · hm^{-2} · a^{-1}); A is the forest age (a); forest age takes average of various tree species.

3.2 The carbon reduction effect of trade of papermaking raw materials in China The total stock volume is 180.5709 million m^3, and there are differences in the estimated average annual amount of carbon sequestration based on different tree species. The average annual amount of carbon sequestration for larch is smallest, while the average annual amount of carbon sequestration for eucalyptus is largest; the average annual amount of carbon sequestration for redpine is equivalent to that for poplar (Table 3). The four tree species represent the main types of timber for papermaking in different regions of China, so the mean value (19021100 t/a) of the average annual amount of carbon fixed is regarded as the estimated value of carbon reduction effect of trade of papermaking raw materials in China in 2012. The trade of papermaking raw materials in China in 2012 saved 36.11418 million t of domestic paper pulp supply, equivalent to 144.45672 million m^3 of wood. The increase in forest stock volume directly leads to increase in forest carbon sinks. In accordance with the tree species commonly used for China's papermaking, the average annual carbon sequestration is calculated at about 17.7341, 9.1637, 31.1600 and 18.0266 million t/a, with the average of 19.0211 million t/a, which is equivalent to the reduction of 19.0211 million t of China's total carbon emissions. Therefore, the carbon re-

duction effect of China's trade of papermaking raw materials in 2012 was 19.0211 million t.

Table 3 Biomass, NPP and annual carbon sequestration of different tree species with the same stock volume

Tree species	Biomass 10^8 t	NPP 10^8 t · a^{-1}	Annual carbon sequestration 10^8 t · a^{-1}
Redpine	2.145161	0.354683	0.177341
Larch	1.267698	0.183275	0.91637
Eucalyptus	2.286876	0.623200	0.311600
Poplar	2.409662	0.360533	0.180266

4 Carbon emission effect of paper and paper product trade in China

4.1 Data selection and research methods The carbon emissions of China's net exported paper and paper products are calculated based on IPCC inventory guidelines, that is, the carbon emissions are estimated by the product of energy consumption and emission factors. The energy consumption data of papermaking industry are from *China Energy Statistical Yearbook*. It is calculated as follows:

$$E_{nx} = \sum_i F_i \times EF_i \times P_{nx}$$

where E_{nx} is the carbon emission of net exported of paper and paper products (t), which is calculated by the amount of carbon dioxide emissions; F_i is the total consumption of energy i (t), which is calculated by the standard coal consumption; EF_i is the efficient carbon emission factor of energy i; P_{nx} is the proportion between net exports and production of paper and paper products.

The fossil energy for papermaking industry mainly includes coal, coking products, all kinds of oil, natural gas, electricity and so on. The carbon emission factors of various types of energy are from the IPCC carbon emission calculation guidelines. The effective carbon emission factors are obtained based on carbon emission factors and coal conversion coefficient (10000 t of coal equal to 2.93×10^{14} J)[11]. Thermal coefficient is based on the heating carbon emission factors in 2012. The electricity emission coefficient is based on the Chinese regional grid baseline emission factor in 2013. Various types of energy carbon emission factors are shown in Table 4, and various kinds of energy consumption is shown in Table 5.

Table 4 The carbon emission factors for various types of energy

Fossil energy	Carbon emission factor 10^{-12} t · J^{-1}	Oxidation rate// %	Effective carbon emission factor// t · t^{-1}
Raw coal	25.8	100%	0.7559
Gasoline	18.9	100%	0.5538
Diesel fuel	20.2	100%	0.5921
Fuel oil	21.1	100%	0.6185
Natural gas	15.3	100%	0.4483
LNG	17.5	100%	0.5128
Heat	/	/	1.0112
Electricity	/	/	0.7595

Note: The carbon emission factor is the amount of carbon dioxide emission due to the consumption of various types of energy; the effective carbon emission factor is the amount of carbon dioxide emission from unit coal consumption; the measurement unit of effective carbon emission factor for electricity is 10^{-6} t · W^{-1} · h^{-1}.

Table 5 The consumption of main types of energy for China's papermaking industry in 2012 Unit: 10^4 t

Fossil energy	Physical volume of consumption	Standard amount of consumption
Coal a	1908.14	1298.05
Gasoline	9.05	13.32
Diesel fuel	20.16	29.38
Fuel oil	7.10	10.14
Natural gas	1.29	16.72
LNG	15.56	27.34
Heat	160652.40	547.82
Electricity	57.90	711.59

Note: The data are from *China Energy Statistical Yearbook* (2013); coal includes rough coal, cleaned coal and other types of washed coal; standard amount of consumption is the converted amount of standard coal consumption; the physical volume of natural gas consumption is calculated in unit of 10^8 m^3; the physical volume of heat consumption is calculated in unit of 10^{12} J; the physical volume of electricity consumption is calculated in unit of 10^{12} Wh.

4.2 The carbon emission effect of trade of paper and paper products in China In 2012, the net exports of paper and paper products in China reached 4.33 million t, accounting for 2.88% of total production of whole industry; the annual energy consumption for papermaking industry was 26.5809 million t, and the total carbon emissions reached 17.83185 million t. Thus the carbon emissions of net exported paper and paper products in China in 2012 were calculated at about 0.5136 t. This value can be used to represent the size of carbon emission effect of trade of paper and paper products in China in 2012. Compared with the carbon reduction effect of trade of papermaking raw materials in China, the carbon emission effect of trade of paper and paper products in China is much smaller. Overall, the trade of paper products in China in 2012 reduced 18.5075 million t of domestic carbon emissions, with significant carbon reduction effect.

5 Conclusions and discussions

5.1 Carbon reduction effect of trade of Chinese papermaking raw materials is significant The results show that the carbon reduction effect of trade of Chinese papermaking raw materials was 19.0211 million t in 2012, equivalent to the average annual carbon sequestration of 180.5709 million m^3 forest, and the carbon reduction effect is obvious. From the actual situation, the contradiction between lack of Chinese forest resources and rapid growth of demand for wood products is very prominent, coupled with logging ban and timber production limitation, leading to growing imports. Import has become an important source to meet domestic demand for papermaking raw materials, and the exports are almost negligible relative to imports. This one-way import trade pattern makes China save a lot of papermaking timber resources, which is bound to bring a huge offsetting effect of carbon emission, namely carbon reduction effect. From this perspective, the trade structure of the Chinese papermaking raw materials is conducive to achieving national carbon reduction goal.

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borrowing funds in western—The case of Luochuan in Shangxi Province[J]. Journal of Northwest Agriculture and Forestry University,2010(5): 33 – 37.
[5] KONG R, HUO XX. An empirical analysis of the trust, guilt, and the choice of peasant household borrowing—based on the three provinces of Gansu, Shaanxi, He'nan[J]. China's Rural Economy, 2009(11):50 – 59.
[6] LI R, ZHU X. Econometric analysis of credit constraints of rural households and welfare loss[J]. Economic Research,2007(2):146 – 155.
[7] LUO JQ. Research on farmer's credit demand class differences in Zhejiang Province[J]. Rural Economic,2010(7):86 – 90.
[8] MA XY, BAI YX. Farmers individual character and credit constraints: comparative analysis of two types of credit market[J]. Soft Science,2011(2):94 – 98.
[9] YANG J. Coverage: the rural financial supply and demand—Based on 20 000 farmer households borrowing situation questionnaire[J]. Review of Financial Development, 2010(3):121 – 135.
[10] ZHAO BQ. Empirical research on farmers folk lending credit rationing—Based on 600 rural households[J]. Social Science Front,2010(4):65 – 71.
[11] ZHU BJ,LU YJ,ZHANG LY Analysis of peasant household borrowing welfare effect under the credit rationing[J]. China's Rural Economy, 2009(6):51 – 61.
[12] ZHANG LY, JIANG C. Theory and empirical analysis of non-price credit rationing in China's rural financial market[J]. Finance Research, 2011(7):98 – 113.
[13] ZHANG J. Farmers, countries and China's agricultural credit system: a long-term perspective[J]. Finance Research,2005(2):1 – 12.
[14] ZHONG CP, XU CS,SUN HM. Credit constraints, demand for credit and peasant household borrowing[J]. Finance Research, 2010(11):88 – 100.
[15] ZHU X, LI ZN. The economic impact of peasant household borrowing—Based on empirical research IVQR model[J]. Systems Engineering Theory and Practice, 2007(2):68 – 75.
[16] ZHU X,SHI QH,LI R. The business investment behavior of peasant households during the period of transition—Based on Yangtze River Delta tracking 15 village farmers[J]. Economics,2010(9):713 – 730.
[17] Inessa Love,Susana M. Sánchez. Credit constraints and investment behavior in Mexico's rural economy[J]. The World Bank, 2009.
[18] Kim Tae-Hun. The measurement of farmer's risk attitudes using a non-structural approach[J]. Journal of Rural Development, 2011, 31(2):63 – 80.
[19] Subhash C. Kochar and S. N. U. A. Kirmani. Some results on normalized spacings from restricted families of distributions[J]. Journal of Statistical Planning and Inference, 1995(46):47 – 57.
[20] Millard F. Long. Why peasant farmers borrow[J]. American Journal of Agricultural Economics,1986, 50(4):991 – 1008.

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5.2 Carbon emission effect of Chinese trade of paper and paper products is not significant Based on IPCC inventory guidelines, it is calculated that the consumption of energy (coal) for China's papermaking industry was 26.5809 million t in 2012, and the total carbon emission was 17.83185 million t. And the carbon emission effect of Chinese trade of paper and paper products was 0.5136 million t in 2012. This result is equivalent to only 2.7% of carbon reduction effect of Chinese trade of papermaking raw materials, and the carbon emission effect is not significant. This is mainly because China is not only a major importer of papermaking raw materials, but also a major producer and consumer of paper products; the production of paper and paper products is mainly to meet domestic consumption, and the net exports of paper and paper products are too trivial or insignificant to mention. In 2012, the national production of paper and paperboard was 102.5 million t, and the production of paper products was 48.04 million t, a total of 150.54 million t. At the same time, the net exports of paper and paper products were only 4.33 million t, accounting for less than 3% of total production. It can be seen that the "pollution haven" hypothesis does not hold in the paper industry.

5.3 Overall, the Chinese trade of paper products has significant carbon reduction effect In 2012, the carbon reduction effect of the Chinese trade of papermaking raw materials was 190.211 million t, and the carbon emission effect of trade of paper and paper products was 0.5136 million t. Overall, the Chinese trade of paper products has significant carbon reduction effect, and the specific value is 18.5075 million t. This result fully proves that the China's trade structure of paper products is conducive to the reduction of domestic carbon emissions, and the offsetting effect is obvious. In summary, the conclusion can provide an important scientific basis for the structural adjustment of China's trade of paper products.

References

[1] WEI BY, FANG XQ, WANG Y, *et al.* Estimation of carbon emissions embodied in international trade for China : An input – output analysis [J]. Journal of Beijing Normal University(Natural Science),2009,45(4):413. (in Chinese).
[2] WANG TF, ZHANG J. Influence of export trade on carbon emission in China[J]. Journal of International Trade,2011,03:89 – 98. (in Chinese).
[3] LI HZ, LIN J. The carbon emission effect of export trade: The evidence from China's industry [J]. International Economics and Trade Research, 2013,29(3):4 – 17. (in Chinese).
[4] ZHANG D, WEI BY, FANG XQ. Carbon emissions embodied in 2002 agriculture international trade for China: An input – output analysis [J]. Journal of Beijing Normal University(Natural Science),2010(6):738 – 743. (in Chinese).
[5] SUN LY, WANG XM, HUANG D. Research on interaction between foreign trade of paper products and the development of China's paper industry [J]. Forestry Economics,2012(11):61 – 65. (in Chinese).
[6] HAN JM. Pulping progress and technology [M]. Beijing: Chemical Industry Press,2005. (in Chinese).
[7] CHEN JC. Papermaking plant resource chemistry [M]. Beijing: Science Press,2012. (in Chinese).
[8] DONG HY, YUN JF, WANG GZ. Summary of carbon storage [M]. Beijing: Science Press,2012. (in Chinese).
[9] FANG JY, LIU GH, XU CL. The biomass and net production of Chinese forest vegetation [J]. Acta Ecologica Sinica,1996,16(5):497 – 508. (in Chinese).
[10] ZHAO M. Study on carbon storage and balance of Chinese main forest ecosystems[D]. The Chinese Academy of Sciences(Institute of Botany),2004. (in Chinese).
[11] ZHAO M,ZHANG WG,YU LZ. Carbon emissions from energy consumption in Shanghai City [J]. Research of Environmental Sciences,2009(8):984 – 989. (in Chinese).