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Study on Dynamic Equilibrium of Carbon Space Transfer in China:Base on the Perspective of Ecological Economy

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Abstract: As a starting point from carbon emissions in economic system and carbon storage in ecosystems, according to coordinated development of eco-economic perspective, the paper constructed mechanisms of carbon transfer, summarized the main factors of carbon transfer in the ecological economic system. The trend comparatively analyses between carbon emissions and storage showed that there was an unbalance of carbon transfer between China and all its provinces. Most of the developed provinces and little undeveloped provinces were carbon transfer unbalance in their ecological economic system, such as the province of Shandong, Hebei, Shan xi, etc. Few provinces were carbon transfer equilibrium such as the province of Fujian, Sichuan, Qinghai, etc.

Key words: *Carbon transfer; Carbon emissions; Unbalance; Eco-economic development*

1. Introduction

In 2011, according to the data from World Bank, Chinese exports accounted for 10%, but its carbon emissions accounted for 25.5% in the world (data.worldbank.org.cn).It concluded that the economic development of our country is a type of high carbon emissions, which strongly interferes environment. Economic development has relationship with carbon emissions, which was the common understanding that the former was the important Granger factor to the latter. As a developing country, China faced two formidable tasks of economy development and ecological environment maintenance.

The 13th Five-Year Plan would set powerful targets for carbon emissions which reduced carbon intensity by 40-45% from 2005 levels by 2020. At present, under the background of controlling global greenhouse gas, we still need some rights to develop economy to promote the coordinated development of ecological economy. Forest ecosystem was of important function for optimizing ecological environment and ecological civilization construction. As the main body of terrestrial ecosystems, it stored about 77% of global carbon in terrestrial vegetation and 39% of global soil carbon (Bousquet P et al., 2000). But its carbon exchange capacity with atmospheric was up to 90% of the terrestrial ecosystem, which told the status of regional ecological environment (Houghton J T et al., 2001). Recently, in order to strengthen regional ecological environmental self-repair function, we invested heavily in the forestry ecological construction. Furthermore, the energy conservation and emissions reduction policy restriction promoted the carbon transfer dynamic balance between emission and collection.

As we known, economic development, urbanization, industrialization and the changes in land usage increased carbon emissions dramatically and affected regional climate, the major reason of which was the rapid growth of the economy and ecological environment of auto-repair unbalances. Especially along with the human life level of ascension, unreasonable human handling of waste (Ying et al., 2015); also can produce huge amounts of carbon emissions. Regardless of how "carbon" in the economic system in the operation of the mobile space, a lot of carbon compounds stays in the atmosphere, greenhouse gases affect the environment and climate change. Regardless of how "carbon" operates in the economic system, a lot of carbon compounds still stayed in the atmosphere to affect the environment and climate change. As the coordinated development of ecological economic perspective, the research object was carbon transfer from the economic and ecological system.

According to the analysis of carbon dynamic balance between carbon emissions transfer in economic development and biological carbon transfer in forest ecosystem, based on the comparative analysis of the existing data and different provinces formed by the net carbon emissions and carbon transfer dynamic balance, it concluded current situation of the development of Chinese economic and ecological environment, which was significance to promote our ecological civilization construction and economic development .

2. Carbon transfer path and mechanism:

Carbon transfer can divide into carbon emissions transfer in economic development system and biological carbon transfer in ecological environment system which the former was the important factor influencing the carbon dynamic balance. Carbon followed national and regional industry needs and trade division and industry or product (carbon source) of high carbon emissions flow among different regions to form carbon transfer. The forest carbon cycle played an important role in the ecological environment, it showed trees absorbed CO_2 from the atmosphere into the forest and soil formed "carbon sink". Reducing CO_2 to offset the carbon emissions in the atmosphere is the dynamic stabilizer between the ecological environment and economic. So, the economy and environment coordinated development between carbon emissions transfer in the economic system and biological carbon transfer in environment system.

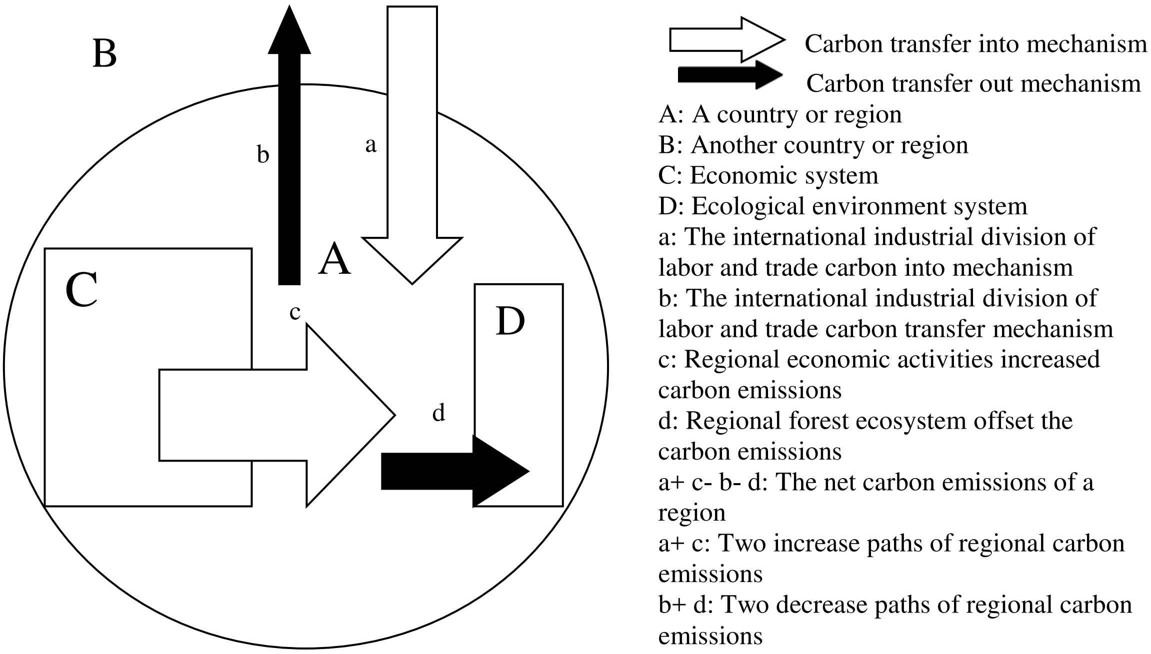

Fig1. *The dynamic balance mechanism of carbon transfer in ecological economic system*

In the whole ecological economy system, through the regional industry transfer and trade division of labor it can realize carbon transfer. Energy consumption is the major result to increase carbon emissions. Its products included construction, manufacturing and textile industrial products. In order to cater to the needs of society, all kinds of industrial activity caused a lot of carbon emissions. Due to different tree species, climatic conditions and even vulnerable to natural risks, so biological carbon transfer effect carbon balance lighter than direct reduction. Which carbon sinks offset the carbon emissions by about 19% (Sun et al., 2010).

As shown in Figure 1, trade import-export and economic development is the major path of carbon transfer in economic system. Forest ecosystem is the main path of ecosystem carbon transfer. Different paths of the carbon transfer are not the same direction. In a word, trade import is a way to transfer our carbon emissions to the other countries. Forest ecosystem is the way to offset the carbon emissions. They both reduce carbon emission; conversely, trade exports and industrial economic activity are the major ways to increase Chinese carbon emissions.

3. Main factors of carbon transfer:

3.1. Factors of carbon transfer in economic system:

In economic system, carbon emissions transfer through industrial structure adjustment and trade. Industrial transfer of economic system transfer the carbon emissions to another area which do not eliminate carbon emissions instead transferring carbon emissions within the system. It is the major way to control high carbon industry development through industrial transfer and adjustment to reduce and control carbon emissions.

3.1.1. Factors from industrial economic development:

Industrial economic development especially industrial production have the important influence on Chinese carbon emissions which produce net carbon emissions to transfer the carbon to the free carbon compounds into the atmosphere. Our second industry and industry take up the important position of GDP in the national economy at 40%-50%. Since 2009, they showed a trend of decline because of industrial adjustment. According to the energy consumption of various industries, industrial energy consumption account for the total energy consumption by about 70%, which is the main department of carbon emissions.

The relationship of the proportion of secondary industry and carbon emissions is proportional (Wu et al., 2012). With per capita GDP unchanged, when the proportion of secondary industry drop down 1%, per capita carbon emissions reduced by 0.3217%. GDP growth is the critical increased amount of carbon emissions (Sun et al., 2010). Base on budget estimate, carbon emissions of Chinese energy consumption from the industrial sector is more than 84%. In the industrial organization, carbon transfer mainly flow by energy conversion, extractive industry, process manufacturing, and discrete manufacturing (Yang, 2015). Our carbon transfer from the regions of rich energy and heavy chemical industry to the region of economic developed and underdevelopment (Shi et al., 2010). With the eastern coastal industrial transfer, Northwest and Northeast become the area of transfer into, but Beijing, Tianjin and the north coastal regions become the transfer out (Xiao et al., 2014). Not only the size but the space, there were many implicit changes of Chinese regional carbon transfer, which trend to the western region especially the northwestern regions. On the contrary, Beijing &Tianjin area and Southeast always the area of transfer out, especially the southeast coastal area by the export (Liu et al., 2014).

3.1.2. Trade factors:

The improvement of trade openness promotes trade carbon transfer, which is the higher openness, the higher export (Hong, 2014). The scale effect and structure of processing trade export and energy intensity effect positively on the carbon emissions (Deng, 2014). International trade through two forms reflected the trend of the carbon transfer. One of the ways is fossil energy import and export which as the carbon source product transfer. With the import and export of carbon emissions coefficient unchanged, its implicit carbon transfer will be increased by its products increased. As a manufacturing country, under the condition of the technology spillover limited, the high pollution and energy consumption enterprises trade for us by higher carbon migration. At the same time, production energy industrial activity is another main cause of carbon emissions.

International industry divide into two carbon transfer China-centric ways ,one of which is input energy industry of high carbon and metal products from Kazakhstan, the Middle East, Australia, Brazil, the Russian federation and India (class Ⅲ) make manufactured goods of medium and low carbon to many countries around the world especially the European and American countries (class Ⅰ). Another way is our input low carbon semi-finished products or components from the ASEAN , South Korea, other Asian undefined regions and Japan (class Ⅱ) to make manufactured goods of medium and low carbon to many countries around the world (Wang et al., 2011). In 1997 and 2002, the amounts of carbon emissions transfer from goods trade between China and the US, was each to 371.975million *t C* and 471.960 million *t C* (Yu et al., 2009). In 1995, 2000 and 2005, due to the added value of Chinese total carbon emissions export to Japan was much more than the added value of Japanese carbon emissions, which existed carbon transfer between them. Scale effect had a positive influence on carbon emissions between China and Japan in the 3 years. Structure effect and technology effect on Chinese carbon emissions transfer's change show negative to positive but Japan not (Wu et al., 2012).

Since China joined the WTO, our energy production and consumption are rising based on carbon source production. It further illustrated that the international trade increase the energy of the export of domestic carbon emissions through carbon transfer. Another way is an import and export of manufactured goods which reflected the producer of carbon emissions by carbon source products production activities. Since 2003, Chinese manufactured exports and imports significantly increase which the former is faster. From the carbon transfer perspective, export on behalf of foreign demand increase domestic carbon emissions and import on behalf of domestic demand increase foreign carbon emissions.

3.2. Carbon transfer factor in ecosystem:

In ecosystem, forest ecosystem is the In the main carbon absorption system, China is to be a country lack of forest resource and high quality forest, so forest management, an important component of cultivation of forest resources, is conducive to promoting forest health and accelerates the growth of green fortune (Zao et al., 2014). Forest carbon sinks as a green fortune which has important functions for carbon offset. Due to the terrestrial carbon deposits mainly existed in the forest ecological system, which play an important function of buffer and valve in the litre geosphere, biosphere biogeochemical process. Forest carbon sinks had much unique superiority than other measures to reduce emissions such as great potential, easy operation, quick effect, low cost, small impact on economic growth, residents' welfare. It not only includes the exchange in afforestation and reforestation carbon sink project, but also includes increasing forest carbon sinks in offset (Huang, 2008). Forest is either carbon sequestration or carbon source. Forest played an important role in the carbon cycle to promote carbon transfer to address climate change of sustainable forest management and management (Clark et al., 2013). The area of the forest ecological system took up a 1/3 of the total land area, which the carbon reserves accounted for 56% of the total terrestrial carbon amount (Zhang, 2014). The decrease of forest area especially the destruction of the rainforests have become the second largest fossil carbon source after fossil burning (FAO, 2011). At the same time, forest soil are important in the global carbon cycle of carbon sources, carbon sinks& library, and its slight change in soil organic carbon library would directly affect the atmospheric concentrations. Once the forest resources are destroyed and degenerate, it will appear carbon reversal. So, it can enhance function of forest ecosystem carbon storage to forest area and volume increase, the improvement of quality, reduction of natural disasters (fire, plant diseases and insect pests) and reasonable tree cutting.

Many scholars estimate our forest carbon storage by forest stock volume. According to the situation of forest resources inventory, the 6^{th}, 7^{th} and 8^{th}, the forest volumes are respectively 12.456, 13.721 and 15.137 billion *cubic meters*, so our forest volume is increasing at present which indicate a increasing trend of carbon storage. Our forest volumes maintain a certain growth which indicates forest resources can not only use and update constantly as raw materials, but also increase volume as renewable resources by continuously increasing investment.

4. The analysis of ecological economic system of carbon dynamic transfer balance:

4.1. Material and method:

The paper employs data from China Statistical Yearbook, Chinese Economic and Social Development Statistical Database and forest resource inventory data per year from 1995 to 2014. A closure system, carbon changes with time in ecological economic system. In the whole dynamic process, carbon changes between emissions and reserve increment to the dynamic trend of transfer balance.

Because energy consumption is the main reason of carbon emissions, the calculation of carbon emissions is according to the estimation of all kinds of energy such as coal (10 thousand *t*), coke (10 thousand *t*), crude oil (10 thousand *t*), gas (10 thousand *t*), diesel (10 thousand *t*), fuel oil (10 thousand *t*) and Natural gas (hundred million *cubic meters*). It adopts Model 1 to estimate the carbon emissions which is used by many scholars such as Cheng et al., (2013).

$$C_e = \sum \varepsilon_i \lambda_i E_i \tag{1}$$

That is: C_e is carbon emission, λ and ε each is coefficient of coal and carbon emissions by IPCC (IPCC, 2006). E is energy consumption, i is energy types, which the natural gas unit conversion coefficient is 1 cubic meter equal to 0.7256*kg*. In this paper, carbon sink is carbon increment that is the balance between total carbon accumulation and the former of the forest resources inventory estimation.

According to the estimation method by Zhang et al., (2010), it calculates the forest carbon storage by forest volume to the model as follows:

$$\Delta Cf = (1+\alpha+\beta)\Delta Vf\,\delta\rho\gamma = 2.439(\Delta Vf \times 1.9 \times 0.5 \times 0.5) \tag{2}$$

That is: ΔCf is forest carbon sequestration; ΔVf is forest volume increment; δ is Biomass expansion coefficient which the forest biomass accumulation change into biological dry weight is carbon content which biological coefficient of dry weight change into the amount of carbon sequestration; α is forest undergrowth biomass computing plants including litter solid carbon as undergrowth solid carbon conversion coefficient; β is the amount of forest carbon sequestration conversion factor according to the forest biomass.

In order to understand the situation of ecological economic development in all regions, the paper established the model as follows:

$$Y = wX_i \tag{3}$$

Y is an area Ecological and economic coordination development index; X_i each is GDP, per capita GDP, the forest coverage rate, the forest volume; w is the weight and equal to 0.25(average weight).

4.2. Analysis of carbon dynamic transfer balance:

According to calculation of the carbon emissions by Model 1, there is little difference between the result of 1.914 billion *t C* (2005) from the research and the result of 2.202 billion *t C* (2005) from Sun et al., (2010) using industry decomposition method. It shows that energy consumption is the main factor of carbon emissions but not the only and other production activities, land use and waste management will also produce a little. According to the Model, Chinese carbon emissions are to about 1.8 *t C* per ten thousand Yuan GDP in 2014. Per capita carbon emissions rise from1.2 *t C* per person in 2003 to more than 2.5 *t C* per person in 2014. The result of Model 2 is in accordance with the result by Zhang et al., (2010), (e.g. the accumulation of the forest carbon total reserve is 14.43 billion *t C* by the sixth forest resources inventory (1999-2003)).

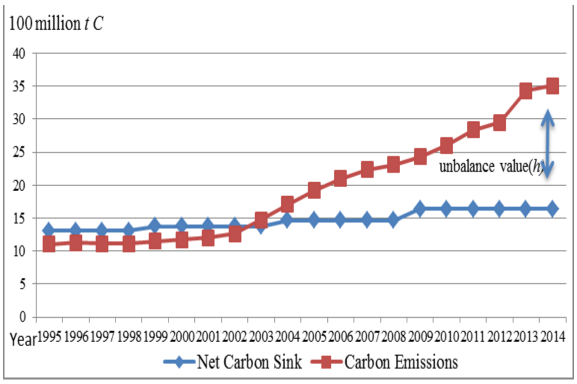

Fig2. *The change trend of carbon storage increment and carbon emissions in China*

The growth of our carbon storage was less than it of carbon emissions (fig.2), which makes unbalance value h of dynamic relationship between emissions and storage increasing gradually. Excessive amounts of carbon emissions and low carbon storage incremental leaded to carbon transfer space unbalance. Carbon emission from the one-off energy consumption result to balance development with carbon sequestration by forest ecosystem before 2002 and unbalance value *h* was little. But since 2002, carbon emissions increases rapidly. Combined with the international background and the analysis of the economic situation, we joined in WTO in 2001, and then we made full use of the information to push the industrialization and vice versa by the 16th Congress. It increased the investment in fixed assets, construction of heavy industry such as steel, cement investment growth of 92.6% and 92.6% respectively, and add some resource consumption, low level of technology, pollution projects (such as cement, electrolytic, etc.) To explain further, there was a positive relationship between economic development and carbon emissions.

From the change trend of carbon storage incremental, it showed our carbon increment grew slowly. Forest ecosystem as a carbon dynamic balance stabilizer absorbs CO_2 to adjust the carbon balance. In the aspect of policies, combined with the relevant preliminary analysis of forestry policies in recent years, we gradually implemented converting farmland to forest and Natural Forest Protection Program etc. In June 2003, Central Committee of the Communist Party of China and State Council made The Decision to Accelerate the Forestry Development to push the collective forest right system reform. In 2004, successful trials were carried out in Guangxi and Sichuan Province. In 2008, we promote the reform of collective forest right system in an all-round way. In 2014, we Full implementation of the stop cutting policy in the state forest region in northeast. These policies were enacted by Chinese government for forestry attention, so as to promote ecological protection and advance ecology economy coordinated development.

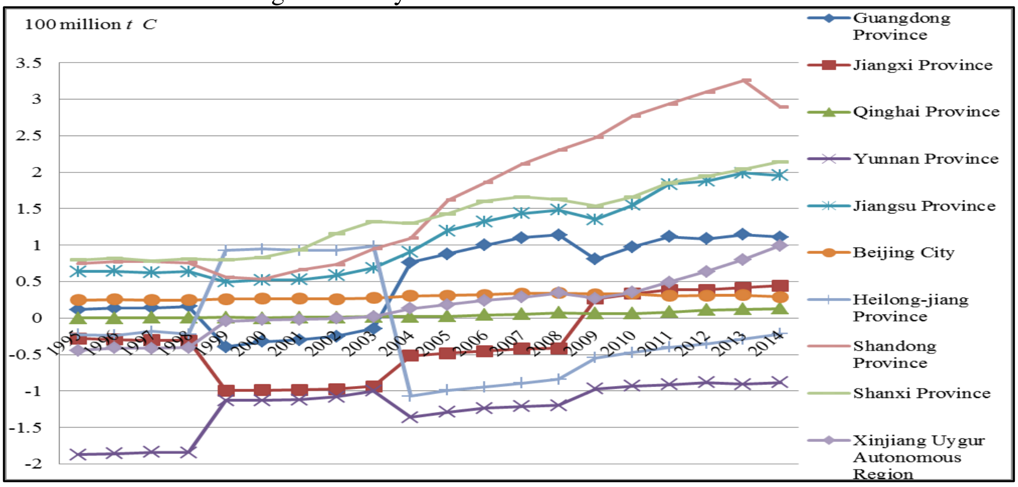

***Fig3.** The carbon transfer dynamic equilibrium (h) in main province (city)*

Note: In the figure, the main provinces were selected from Chinese eight major region geopolitical pattern; they are the northern coastal, central, east coast, southern coastal, southwest, northwest, northeast, Beijing & Tianjin area

In order to analysis of regional carbon dynamic trend of transfer balance further, the paper used average comparison method, according to the four indexes such as economic development (economic output and per capita GDP) and the ecological environment level (forest and forest volume) respectively the comprehensive ranking of the weight of 0.25 of different provinces in 2014 (as shown in model 3), it showed that coastal areas in southeast provinces are top, the northwest area reverse.

As Fig 3, the change value of *h* in most provinces between carbon emissions and carbon storage was consistent to the national trend which there was sharp changes in the top right and some of them were fluctuations in 1999, 2004 and 2009, then become normal. After examination, it concluded that six major project of forestry in China to implement and forestry carbon sequestration project implementation result in volume of volatile unbalance impact value change.

***Table 1:** Average h and GDP change value (rank) in latest 10 years, Unit: billion Yuan*

Province(city& region)	Average *h*	GDP Change Value(Rank)	Province(city& region)	Average *h*	GDP Change Value(Rank)
Shandong	2.12	4,090.96(3)	Hunan	0.23	2045.24(9)
Hebei	1.72	1,930.42(10)	Gansu	0.22	490.13(25)
Shanxi	1.59	852.89(22)	Hubei	0.15	2,077.68(7)
Jiangsu	1.36	4,648.96(1)	Qinghai	0.06	175.78(28)
Liaoning	1.23	2,057.93(8)	Jilin	0.05	1,018.35(19)
Henan	0.94	2,435.20(5)	Hainan	0.02	258.19(26)

Guangdong	0.87	4,523.48(2)	Inner Mongolia Autonomous Region	-0.01	1,386.45(15)
Zhejiang	0.47	2,673.58(4)	Guizhou	-0.08	724.56(23)
Tianjin	0.41	1,202.49(16)	Jiangxi	-0.19	1,163.86(17)
Beijing	0.32	1,436.13(13)	Sichuan	-0.25	2,115.16(6)
Anhui	0.31	1,547.28(12)	Fujian	-0.40	1,748.68(11)
Xinjiang Uygur Autonomous Region	0.30	662.45(24)	Guangxi Zhuang Autonomous Region	-0.50	1,159.7(18)
Ningxia Hui Autonomous Region	0.29	213.95(27)	Heilong-jiang	-0.55	952.57(20)
Shaanxi	0.28	1,401.42(14)	Yunnan	-1.10	934.16(21)

Note: Due to incomplete statistics data, the regions of Shanghai, Chongqing and Tibet were not included. The change value of GDP was from the value of 2014 minus 2005

It uses the changes of the value h and economic aggregate GDP to analyze the relevance between economic growth and the coordinated development of ecological economic system. The value h is closer to zero which are closer between carbon emissions and carbon storage so that carbon transfer more balance. The trend line is deviates from the value of the zero to be positive values that the growth of carbon emissions is quicker than carbon storage. It means the carbon transfer more unbalance. The trend line is more far away zero to be negative that the stronger self-repair function, higher forest storage volume and weaker economic development on interference ecological system. As shown in table 1, in the decade the average value h of Shandong was over 2, Hebei, Shanxi, Jiangsu, Liaoning between 1 and 2 , Henan and Guangdong between 0.5-1, Zhejiang, Tianjin, Beijing, Anhui, Xinjiang Uygur Autonomous Region, Ningxia Hui Autonomous Region, Shaanxi, Hunan, Gansu, Hubei between 0.1-0.5, Qinghai, Jilin and Hainan between 0-0.1, the Nei Monggol Autonomous Region, Guizhou, Jiangxi, Sichuan, Fujian, the Guangxi Zhuang Autonomous Region, Heilongjiang and Yunnan less than 0.

4.3. Result:

Combined with GDP change trend and the situation of forest ecological, the bigger value h of provinces (except Shanxi) was the quicker economic growth. It shows that the influence of economic growth on carbon emissions growth was greater than the carbon growth in forest ecosystems which the unbalance value h in Shandong was the largest. Economic growth change of Shandong province has ranked top 3 but the forest coverage rate had been only 16.73% which stated that the economic rapid development was unbalance with development of the ecological environment. It had been the same as Hebei, Jiangsu, Liaoning, and Henan, which their forest coverage rate each was 23.41%, 15.80%, 38.24% and 21.50%. Guangdong, Zhejiang, Hunan and Hubei had better, which the forest coverage rate each was 51.26%, 59.07%, 47.77% and 38.40%. Shanxi has been higher h but slow economic speed, which was not harmonious to ecological economic development. Its forest coverage rate had been only 18.03% and the ecology and economic system both fragile, which was economic development pattern of the high carbon emissions and large disturbance on the ecological environment. Except Shanxi, the economy in Xinjiang, Ningxia, Gansu and Qinghai all increase slowly and the value h had been positive, which the forest coverage rate each was 4.24%, 11.89%, 11.28% and 5.63%. It had showed that their situations were similar to Shanxi. The economy and forestry ecological development in Beijing both increase rapidly, which the forest volume had raised 24%, 37% and 69% respectively in the 6th , 7th and 8th during the same period but it was only 9.87% in Tianjin. The ecological economy development coordination of Fujian and Sichuan had been better, which their rate each were 65.95% and 35.22% and their forest stock volume each ranks the 7th and the 2nd. Other unbalances development provinces with negative values had been the big province of forestry which their forest stock volume was higher; there had been Inner Mongolia autonomous region, the province of Guizhou, Jiangxi, Guangxi Zhuang autonomous region, Heilongjiang and Yunnan ranking in 5th, 14th, 9th, 8th, 4th and 2nd. But there had been inharmonious factors, especially Guizhou, Yunnan and Heilongjiang; they needed to speed up the pace of economic development.

5. Conclusion:

The stability of the regional ecological system is the premise of economic development. According to the analysis of carbon dynamic transfer balance of many regions in China, inconsistent development of ecological environment and economic development will lead to the carbon transfer unbalances between ecological and economic system whatever the economically developed provinces or economically backward provinces. Land forest ecosystem carbon transfer, plays an important role in regional economic and ecological development as valve and stabilizer, but its carbon storage function effect on carbon balance transfer less than the direct reduction measures limited by the long-term forestry production and benefits of hysteresis. At the same time, in the case of fragile ecological system, the operation of the economic system is bound to seriously interfere with the development of the ecological environment. Especially, the excess carbon emissions and weak forest ecosystem carbon storage leading carbon transfer unbalance to affect the harmonious development of ecological economy in Beijing, Tianjin, Shanxi Province and northwest regions. We should speed up the pace of ecological environment construction, improve the state of carbon transfer unbalances and guarantee the sustainable development of ecological economic system in Shandong, Hebei, Liaoning, Henan, Guangdong and Zhejiang province with the rapid economic development. We should speed up the economic development in Guizhou, Heilongjiang and Yunnan which is better ecosystem carbon storage function but economic development is relatively slower. Therefore, with the condition of the rapid development of economy, firstly, we should strengthen ecological environment construction to avoid the rapid deterioration of the ecological environment leading to the adverse effect of operation of the system. Secondly, we need improve energy efficiency, adjustment and upgrading of industrial structure, regulating to balance regional ecological and economic system to maintain the sustainable development by two hands.

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