

Pros and cons of climate change in China

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Climate change strongly affected the structure and functions of natural ecosystems, e.g. the vegetation productivity decreased in the Northeast permafrost region due to the higher temperature and less precipitation, whereas in the Tibetan Plateau, the vegetation productivity increased, owing to the improved thermal resource. Climate change led to reduced precipitation in North and Northeast China and thus the reduced surface runoff. The public needs for energy were changed because of climate change, e.g. the shorter heating period in winter. Climate change profoundly influenced human health, pathophoresis and major projects by increasing extreme events, including frequency and magnitude, and causing more serious water shortage. Under the background of climate change, although the improved thermal resources can be helpful for extending the crop growth period, more extreme events may result in more instability in agricultural productivity. Not only did climate change indirectly affect the secondary and tertiary industries through the impacts on agriculture and natural resources, but also climate change mitigation measures, such as carbon tax, tariff and trading, had extensive and profound influences on the socioeconomic system. Further analysis indicated that the impact of climate change presented significant regional differences. The impact had its pros and cons, while the advantages outweighed the disadvantages. Based on the above analysis on the impacts of climate change, we put forward suggestions on coping with climate change. First, scientifically dealing with climate change will need to seek advantages while avoiding the disadvantages of climate change in order to achieve the orderly adaptation to climate change, which is characterized with "Overall best, long-term benefit." Second, quantitative adaptation should be given more attention, e.g. proposing operational schemes and predictable goals and using uncertainty analysis on adaptation measures. Third, more active coping strategy should be adopted to enhance China's future comprehensive competitiveness. The strategies include but are not limited to gradually adjusting the industrial structure, intensifying the research and development (R&D) of emission reduction technology and actively responding to the influence of carbon tax, tariff and trading on socioeconomic development in China.

Keywords: climate change; pros and cons; orderly and quantitative adaptation; active responses; China

Climate change has become a mutual and significant challenge to the countries of the world. Compiling "National Assessment Report on Climate Change" is the basic work for China to cope with climate change; however, due to new international circumstances and national demands, China should continue to compile the third "National Assessment Report on Climate Change." Hence, as one of the core topics of the Xiangshan Meeting, an academic seminar with the topic of summarizing and evaluating the key issues related to the third National Assessment Report on Climate Change was held in Xiangshan Hotel in Beijing on 18 and 19 June 2013. The influence of climate change was highly emphasized and discussed by the scholars attending the meeting. The seminar pointed out that a core and basic question to current China was: to what level does climate change impact China's natural, socio-economic system? How can one scientifically define the advantages and disadvantages of this impact? Although the state and the local governments had compiled a series of strategies to cope with climate change and carried out

some practices, in terms of considering the following questions on how to take different actions, properly apply the positive impact of climate change and avoid negative risks based on advantages and disadvantages of climate change, we should scientifically consider and assess the impact and degree of climate change, so as to realize and cope with climate change in order to maintain sustainable development of economy and the society. In the Xiangshan Meeting, Counsellor Liu Yanhua, who is also the group leader of compiling the third "National Assessment Report on Climate Change", arranged the following work and prepared a special report on the positive and negative relations of global climate change to China, deterministic and non-deterministic relations of climate change, national strategies related to global climate change and mitigation and adaptation of climate change. He also pointed out the importance of breaking through the bottleneck in policy and research, and shorten the gap between China's development strategy and international strategy to climate change research. Based on this

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meeting, the authors summarize relevant research achievements in this paper.

1. The general impacts of climate change on different fields and regions of China

The general impacts of climate change mainly include the direct impact on different fields and regions, the indirect impact on different fields and regional socioeconomic systems by affecting the hydrothermal pattern and resources and environmental carrying capacity, and the indirect impact of mitigating climate change on socioeconomic systems.

1.1. Different fields

- (1) Natural ecosystem and biodiversity: climate change visibly affects distribution, productivity and service functions of the natural ecosystem and causes damages such as reduction of species and degradation of habitats. Vegetation productivity decreased in the Northeast permafrost region due to the higher temperature and less precipitation (Mao et al. 2011). Vegetation net primary productivity decreased in Northern farming-pastoral ecotone (Li & Pan 2012), while net primary productivity in Xinjiang and Qinghai-Tibet regions was on an increasing trend (Zhang 2010). Vegetation in most of central Inner Mongolia was generally stable, vegetation coverage in a few areas obviously improved and some areas saw a strong vegetation degradation and land desertification trend (Wang et al. 2010; Zhang et al. 2011). Impacts of climate change on natural ecosystems include distribution and change of tree species, elevation of timberline, change of phenological phase, increased productivity and carbon sequestration, and more forest fire and plant pests (Guo 2008; Zhang, Zhou, et al. 2008; Fang, Yang, et al. 2010; Dai et al. 2013; Guo et al. 2013).

Climate change caused variation of species richness and biodiversity and eliminated some species in the original habitat (Ma & Jiang 2006; Yuan & Ni 2007), e.g. compared with the middle term of the last century, 26 kinds of birds such as bean goose, *Turdus rubrocanus*, *Circus aeruginosus*, quail and *Panurus biarmicus* disappeared in the Qinghai Lake region in eastern Qinghai-Tibet Plateau. Climate change caused variation in the distribution scope of pests, resulted in more harmful effects of pests and deteriorated species habitat (Zhao 2007; Li et al. 2008; Wu & Liu 2008).

- (2) Natural resources (water, energy, etc.): Precipitation variation trends differed in each

region due to climate change. Generally, precipitation in western China was in an obvious increasing trend, but decreased in most regions of Northern and Northeastern China and increased in Southern China (Zhang et al. 2007). The measured runoff in Northern China rivers such as Haihe River, Yellow River and Liaohe River sharply decreased.

Energy demands of human production and living varied with climate change, e.g. increased winter warming in North and decreased heating days (Chen et al. 2006). Due to the high temperature in summer, air conditioning technologies, architecture structure and insulation level were faced with new requirements (Chen & Ye 2005). Meanwhile, mitigation of climate change needed the reduced dependence on traditional fossil energy and the increased proportion of new energy and renewable, which could further affect energy supply structure (IPCC 2007a).

- (3) Primary industry (agriculture): The impacts of agricultural climatic resource change on agricultural production had their pros and cons. In Northwestern China, on the one hand, thermal resources in the arid region improved, crop growth period extended and natural vegetation climatic productivity increased. On the other hand, agriculture production became increasingly unstable because of more extreme temperature events, including thermal and cold damages in arid region, decreased light resource and serious shortage and uneven distribution of water resources (Sun et al. 2010). Owing to the continuous increase of thermal resources in Northeast, the crop planting structure changed greatly (Ji et al. 2012). National planting boundary moved northward in different degrees. North cropping boundary of winter wheat and double-cropping rice moved northward. Ripe system variation increased per unit area yield in cropping boundary changing area. However, North boundary of stable yields of rain-fed winter wheat and summer corn moved southeastward because of reduction of precipitation (Yang, Li, et al. 2010). Yields of wheat, corn and soybean decreased by 1.27%, 1.73% and 0.41%, respectively, and rice increased by 0.56% due to climate change during 1980–2008 including temperature, precipitation and solar radiation. The most sensitive crops affected by climate change were corn and wheat in the arid and semi-arid regions in North and Northeast. Climate change negatively affected corn and wheat production through direct and indirect impacts (global warming-aggravated drought) (Tao et al. 2012; Xiao et al. 2013).

- (4) Secondary and tertiary industries (industry, building industry and tourism): Climate change had comparatively small direct impacts on industry, but climate change indirectly affected the secondary and tertiary industries through the impacts on agriculture and natural resources. Production and price of agricultural products change with the impact of climate change on agricultural production, thereby affecting industrial sectors whose raw materials are agricultural products (Zhang & Miao 2001).

Climate change affected industrial production allocation and decision making through its impact on availability of water and land resources or transportation and traffic cost. Climate change brought a growing demand on industrial products such as air conditioning, cool drink and beer, and enlarging production scale (Chen et al. 2005).

Compared with industrial production, building industry and tourism were greatly affected by climate change, especially extreme weather and climate events. Climate change increased the frequency and strength of extreme weather, i.e. storm, thereby threatening the schedule of construction and safety level and increasing the requirements for safety, applicability and durability of buildings (IPCC 2007b; Li, Zhang et al. 2012). Environmental landscape and biodiversity were adjusted and local natural features and humane tourism resource were damaged through the impact of climate change. Transportation slowed to a near standstill or even caused a traffic jam because of extreme weather caused by climate change. Besides, sudden change of temperature and humidity in the short term affected the number of tourists and stay time, thereby affecting the benefits of tourism (Liu et al. 2011; Zhong et al. 2011).

- (5) Social system (city, public health and major projects): More extreme weather events and less water resources caused by climate change had a great impact on social and living development. Increasing frequency of precipitation caused more city floods (Chen 2010). High temperature and heat wave not only directly affected human health (Chen et al. 2008; Qian et al. 2010), but also increased the risk of pathophoresis (Lu et al. 2010; Yang, Yang, et al. 2010, Yang, Pan, et al. 2010). Climate change greatly affected major projects that were highly sensitive to climate change (Wang et al. 2003, 2008; Cheng 2004; Kang 2004; Dai et al. 2007; Ren et al. 2008) such as coastal nuclear plant project, Three Gorges Project, south-to-north water diversion project, mountain hazard protection project, highway and railway project in cold region, project for prevention and control of

desertification and soil and water conservation, and inland river basin comprehensive management project.

- (6) Natural damage: Affected by climate change, frequency and strength of extreme weather events significantly increased (Zhang et al. 2007; Zhang & Qian 2008; Zou et al. 2010), including extreme drought, flood, snow and frost, high temperature and heat wave. Durations of annual extreme high temperature increased, whereas durations of annual extreme low temperature decreased. The arid trend in North and Northeast reinforced, and frequency and strength of flood in the middle and upper stream of Yangtze River and Southwestern China significantly increased.

1.2. Different regions

The total climatic warming-drying trend in Northern China intensified the severe situation of water resources, while the increasing thermal resource affected agricultural yield and distribution in this region through the influence of climate change (Fei et al. 2007; Tan et al. 2009). The significant feature in Northeast was the increasing thermal resource and more severe drought in the western area of Northeast; the crop planting area extended due to rising cumulative temperature (Shi, Chen, Yao, et al. 2008). The most significant influence of climate change on Eastern China was the harmful influence of high temperature and heat wave on human health (Tan et al. 2008) and more severe flood damage. Flood damage was exacerbated, wetland area decreased and insect-borne diseases such as *Schistosomiasis* and *Oncomelania* spread more rapidly in Central China in recent years (Zhou 2007; Huang & Xiong 2008). In South China, the numbers of tropical cyclone decreased and its strength increased, the sea level sharply rose and the ecosystem in mangrove and coral reef deteriorated (Han et al. 2006; Hu et al. 2008; Shi et al. 2008). Warming trend was seen in most regions in Southwest while the temperature in Sichuan Basin dropped, the frequency and degree of flood and drought were intensified and mountain hazards tended to happen more frequently. In Southwest, biodiversity decreased, ecosystem deteriorated and Karst rocky desertification aggravated (Moseley 2006; Cheng & Xie 2008; Cui 2008; Hai et al. 2008; Jiang et al. 2008). In Northwest, the impacts of climate change mainly were glacial retreat, increased total amount of precipitation and agricultural yield growth (Ding et al. 2006; Zhang, Deng, et al. 2008).

1.3. Impact of mitigation of climate change on China's socioeconomic development

Although climate change directly affected the socioeconomic system, it mainly affected socioeconomic

development in China through impacts brought about by adaptation or mitigation of climate change, i.e. indirect impacts brought by taking mitigation measures. Those measures, including economic policies involving carbon tax, carbon tariff and carbon trade and promotion of low-carbon technologies, would profoundly affect society and economy (Wang et al. 2005; Research Institute for Fiscal Science Research Team 2009; Bao et al. 2010; Luan et al. 2013a).

In the short term, mitigation measures had a negative impact on the socioeconomic system in China, especially on industries with high energy consumption. In the long term, those negative impacts will gradually be offset by positive impacts, e.g. helping extend government tax and low-carbon economic investment, promoting the development of energy-saving and emission-reduction technology, clean energy industry and green economy. Impacts of different mitigation measures on society and economy can be summarized as follows:

- (1) Carbon tax effectively decreased carbon emission, but it paid the economic development prices in that the output of energy-intensive industries decreased and economic growth rate slowed down. A number of researches show that carbon tax played a significant role in reducing carbon emission, but carbon tax raised the energy use price and production cost in energy-intensive industries (high-emission industries) and negatively affected its output and export. Although due to resources allocation effect, carbon tax promotes output and export of low carbon emission industries, China's economy, generally, is dominated by industries with high energy consumption or high emission; therefore, China's total economic growth, socioeconomic welfare and employment will be negatively affected (Luan et al. 2013a).
- (2) Developed countries imposing carbon tariff did not significantly affect global carbon emission reduction, but it negatively affected China's goods exports and economic development. The United States and European Union may impose carbon tariff on countries that will not set target for reduction in carbon emission, which is helpful for keeping their competitive power. China is the largest export country in the world, and has higher embodied carbon emission in export products. Carbon tax tariff of developed countries negatively affected output, export of China's industries with high energy consumption and economic development (Shen & Li 2010; Zhang 2011; Luan et al. 2013b). Especially, carbon tariff policy had a stronger emulating effect; hence, carbon tariff of developed countries affected China's

economy in the short term. Recent researches showed that carbon tariff was helpful in reducing global emission but its role is limited.

- (3) Low-carbon environmental protection technology helped in the transformation and upgrade of national companies and reduced carbon emission. Although it negatively affected China's economy in the short term, in the long term it helped cultivate new industry and new economic growth point (Zhang & Li 2011; Yao & Cai 2012). In the short term, low-carbon emission technology required companies to add equipment and technology investment and increase the production cost of companies, and exerted a negative influence on national production and market share as well as on goods export. In the long term it improved energy use efficiency, reduced long-term average production cost of companies, promoted transformation and upgrade of companies' production and improved long-term competitive ability of companies. Development and industrialization of low-carbon emission technology would lead to new industries such as new energy sectors and new economic growth point, and bring new impetus to socioeconomic development.

2. The advantages and disadvantages of climate change

2.1. Advantages

Advantages of direct impacts of climate change on China included the following aspects: (1) Global warming increased the per unit area yield of crop in areas with changing cropping boundary in parts of areas in North. (2) Thermal resources in parts of the alpine region increased, crop growth phase extended in Qinghai-Tibet Valley, Northeastern region, and planting varieties and scopes greatly increased. (3) Precipitation in Northwest increased, in a trend from climatic warming-drying to warming-wetting. Vegetation coverage in some regions such as Qinghai-Tibet Plateau and Inner Mongolia was improved, curbing the trend of desertification. (4) In the short term rising temperature may increase crop yield. (5) More glacier melting water increased runoff in rivers such as Tarim River, and promoted the development of oasis agriculture in Northwestern arid area. (6) Biomass carbon sink of Chinese forest increased. (7) Climate warming simulated the increasing demand of industrial products such as air conditioning, cool drink and beer and promoted its production scale.

Advantages of indirect impacts of mitigation measures of climate change (1) helped in the application and

utilization of energy-saving technology and clean energy, and created new industrial sectors and new economic growth points; (2) promoted economic growth mode to take low-carbon economic development mode, effectively decreased reliance of economic development on fossil energy and reduced pollutants emission, and provided valuable opportunities for green development of economy.

2.2. Disadvantages

The direct impact of climate change in the recent term is not obvious, but the negative impact of high-amplitude warming in the mid and long terms is obvious, including: (1) frequency and strength of extreme weather events caused by climate change increased and may cause large natural damage losses. (2) Spatial difference of temporal and spatial variation of precipitation causes uneven temporal and spatial distribution of water resources, frequent occurrence of flood and drought, and more intense water shortage in some areas. (3) Warming by a large margin will aggravate the vulnerability of the ecosystem, decrease productivity and ecosystem services, cause habitat degradation and biodiversity loss, and even lead to extinction of some types of species. (4) Sea level rise in coastal area, increase in frequency and strength of storm surges, coastal erosion and saline tide water intrusion are reinforced, and ecological coastal zone will be greatly impacted. (5) Extreme agricultural meteorological events decrease crop yields and increase agricultural pests damage. (6) Climate change threatens human health and major project construction. (7) Extreme climate has a large impact on tourism.

Indirect impacts of adaptation or mitigation of climate change will negatively affect China's socioeconomic development in the short term, including (1) increasing the production cost of companies, increasing the production price of national products and negatively affecting the output and export of companies with high emission; and (2) negatively hindering the rate of growth of national economy, GDP and employment.

3. Suggestions of coping with climate change

To effectively cope with climate change, we should reasonably apply its advantages while avoiding its disadvantages, and realize the targets of national sustainable development. Therefore, the authors put forward the following suggestions.

3.1. Seek advantages and avoid disadvantages

Seeking advantages is an important aspect of coping with climate change, which is mainly shown in agriculture. According to the fact of climate being warmer or the

scenario of climate going to be warmer in the future, advantages such as thermal resource and extended frost-free period brought by climate warming should be fully utilized. Measures, such as adjusting planting structure and crop allocation, changing cropping system, improving multiple-cropping index and developing new variety, should be taken in order to produce higher yields, ensure the safety of national food and grain. At the same time, we should develop off-season fruits or vegetables (Zhao et al. 2010; Zhou & Zhu 2010; Xie et al. 2011; Ji et al. 2012).

When seeking advantages, due to the negative impacts of climate change to agriculture, water resources, ecosystem and biodiversity, offshore and coastal zone environment, energy, major projects, industry, transportation and regional development, the following adaptation measure to avoid the disadvantages of climate change should be taken: formulating the adaptation of national strategies, monitoring and assessing climate change impact and risk, developing and applying adaptive technology, investing funds of adaptation of climate change, improving public sense and strengthening international exchange and cooperation (Li & Wang 2010; Ouyang et al. 2010; Zhang 2010; Zhang et al. 2010; Zhao et al. 2010; Zhou & Zhu 2010; Wu et al. 2011; Xie et al. 2011; Zhou et al. 2011; Ji et al. 2012; Ren 2012; Song 2012).

3.2. Orderly adaptation

To avoid the negative impacts made by human adaptation activities that were in disorder, relevant scientific researches should be carried out. On this basis, orderly adaptation was shaped by coordinating different departments, as a result realizing scientifically coping with climate change, and achieving the goal of "orderly adaptation, overall best and long-term benefit." This includes the following aspects: improving adaptive ability to deal with climate change, reinforcing experiment and comprehensive assessment model research of climate change and impact mechanism of extreme weather events, carrying out analysis on the vulnerability and risk of climate change impact, evaluating the comprehensive impact of climate change that has happened and globally continued warming scenario on different fields and regions; strengthening combined research on climate change adaptation and regional socioeconomic development planning and combined research on climate change adaptation and socioeconomic development planning in less-developed regions, carrying out formulating of adaptation policies, rules and laws, and international cooperation research in the field of dealing with climate change (Liu et al. 2013); reinforcing collaboration of different departments and fields, strengthening connection of multidimensional knowledge and subjects, closely uniting current policies,

planning, resource management, community development, living ability improvement, decision-making process of sustainable development and risk management and reinforcing adaptation ability (Fang, Qin, et al. 2010).

3.3. Quantitative adaptation

Research on quantitative adaptation to climate change should be reinforced and necessary actions should be taken. Quantitative adaptation mainly include (1) strengthening the monitoring and assessment of the quantitative impact and risk of climate change, and distinguishing the impact of different driving factors, thereby establishing quantitative targets to cope with climate change, (2) strengthening the analysis of quantitative benefit about adaptive technology and measures, and quantitatively evaluating the adaptation effects using cost-benefit analysis, multi-target analysis and risk-benefit analysis (Li, Qiu, et al. 2012; Huang et al. 2013), and (3) using quantitative and qualitative methods, uncertainty analysis shall be used to analyze different adaptation measures and technologies, in order to define their risk, suitability and priority, judge its adaptive effect and provide a scientific basis for adaptation measures in different periods in the future (West et al. 2012).

3.4. Actively cope with climate change

Mitigation of climate change or emission reduction will reduce the rate of Chinese economic development, especially economy and employment growth in the short term; therefore, the following policy suggestions are put forward: (1) gradually adjusting the national industrial structure, supporting the development of low-carbon industries, effectively decreasing the proportion of industries with high carbon emission in national economy before carbon tax and tariff are imposed at home and abroad so as to reduce the impact of carbon tax and tariff in the future on national economic development; (2) profoundly studying the impact of carbon tax, carbon tariff and carbon market on China's socioeconomic development, and making a preparation of system arrangement and policy measures to deal with circumstances of developed countries imposing carbon tariff, and China imposing tariff and establishing the carbon market.; (3) profoundly studying the cost and benefit of emission reduction technology and evaluating the targets of emission reduction and economic growth; (4) intensifying the research and development (R&D) of emission reduction technology, introduction of technology and economic structure adjustment and promoting energy-saving and emission-reduction technology and development of clean energy industry, in order to lead to the growth of new industries and a new economic growth point in China.

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