Climate Change Mitigation in China

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夫君子之行，静以修身，俭以养德。

非淡泊无以明志，非宁静无以致远。

夫学须静也，才须学也，非学无以广才，非志无以成学。

——诸葛亮 《诫子书》

Acknowledgements

My family name is "Xu", one of which Chinese paraphrases is "Promise". My given name is "Bo", one of which Chinese paraphrases is "Ph.D.". Therefore, Ph.D. study is my "manifest destiny" in a sense.

I came to the department of Industrial Ecology, KTH and started my Ph.D. study in 2007, autumn. It is the most beautiful autumn I have seen and I will never forget. Now it is nearly the end of this wonderful experience so I want to express my gratitude to everyone who supported me and gave me help in the past four years and a half.

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Finally, I want to express my deepest gratitude to my mother land. It's time to go home.

Bo Xu

Stockholm, March 2012

许博

二零一二年三月 于 斯德哥尔摩

Abstract

China has been experiencing great economic development and fast urbanisation since its reforms and opening-up policy in 1978. However, these changes are reliant on consumption of primary energy, especially coal, characterised by high pollution and low efficiency. China's greenhouse gas (GHG) emissions, with carbon dioxide (CO_2) being the most significant contributor, have also been increasing rapidly in the past three decades. Following the principle of 'common but differentiated responsibilities', China does not need to undertake any limitation or reduction commitment in the Kyoto Protocol's first commitment period 2008-2012. However, the exponential growth in China's GHG emissions has been heavily condemned in recent international negotiations on climate change mitigation. Responding to both domestic challenges and international pressure regarding energy, climate change and environment, the Chinese government has made a point of addressing climate change since the early 2000s. This thesis provides a comprehensive analysis of China's CO_2 emissions and policy instruments for mitigating climate change.

In the analysis, China's CO_2 emissions in recent decades were reviewed and the Environmental Kuznets Curve (EKC) hypothesis examined. It was found that China's CO_2 emissions have been increasing at a rate of 5.27% per annum reflecting a similar increasing trend in primary energy consumption and economic development in recent decades. Using the mostly frequently studied macroeconomic factors and time-series data for the period of 1980-2008, the existence of an EKC relationship between CO_2 per capita and GDP per capita was verified. However, China's CO_2 emissions will continue to grow over coming decades and the turning point in overall CO_2 emissions will appear in 2078 according to a crude projection assuming economic growth to be 10% per annum. In addition, any relationship based on data in the past can be changed and a new relationship can be established when new statistics are available. More importantly, CO_2 emissions will not spontaneously decrease if China continues to develop its economy without mitigating climate change. On the other hand, CO_2 emissions could start to decrease if substantial efforts are made.

China's present mitigation target, i.e. to reduce CO_2 emissions per unit of GDP by 40-45% by 2020 compared with the 2005 level, was then evaluated. Three business-as-usual (BAU) scenarios were developed and compared with the level of emissions according to the mitigation target. The calculations indicated that decreasing the CO_2 intensity of GDP by 40-45% by 2020 is a challenging but hopeful target.

To study the policy instruments for climate change mitigation in China, domestic measures and parts of international cooperation adopted by the Chinese government were reviewed and analysed. Domestic measures consist of administration, regulatory and economic instruments, while China's participation in international agreements on mitigating climate change is mainly by supplying certified emission reductions (CERs) to industrialised countries under the Clean Development Mechanism (CDM). The most well-known instruments, i.e. taxes and emissions trading, are both at a critical stage of discussion before final implementation. Given the necessity for hybrid policies, it is important to optimise the combination of different policy instruments used in a given situation.

The Durban Climate Change Conference in 2011 made a breakthrough decision that the second commitment period under the Kyoto Protocol would begin on 1 January 2013 and emissions limitation or reduction objectives for industrialised countries in the second period were quantified. China was also required to make more substantial commitments on limiting its emissions. The Chinese government announced at the Durban Conference that China will focus on the current mitigation target regarding CO_2 intensity of GDP by 2020 and will conditionally accept a world-wide legal agreement on climate change thereafter. However, there will be no easy way ahead for China.

Key words

China, Climate change mitigation, Environmental Kuznets Curve (EKC) hypothesis, Mitigation target, Business-as-usual (BAU) scenarios, Policy instruments

Glossary

ADF: Augmented Dickey-Fuller

AHP: Analytic Hierarchy Process

APP: Asia-Pacific Partnership on Clean Development and Climate

BAU: Business-as-Usual

CBA: Cost Benefit Analysis

CDM: Clean Development Mechanism

CER: Certified Emission Reduction

CET: Carbon Emissons Trading

CO_2/GDP: CO_2 emissions per unit of Gross Domestic Product

CO_2e: CO_2 Equivalence

COD: Chemical Oxygen Demand

COP15: the Copenhagen Summit

CPC: the total CO_2 emissions per capita

CPGPRC: the Central People's Government of the People's Republic of China

EC/GDP: Energy Consumption per unit of Gross Domestic Product

EC: Energy Consumption

ECCP: the European Climate Change Programme

ECPC: Energy Consumption per capita

EE: Energy Efficiency

EKC: Environmental Kuznets Curve

ETS: Emission Trading Schemes

EU ETS: European Union Emissions Trading Scheme

EUAs: European Union Emissions Trading Scheme Allowances

G77: The Group of 77

GDP: Gross Domestic Product

GHG: Greenhouse Gas

GPC: GDP per capita

IEA: International Energy Agency

IPCC: Intergovernmental Panel on Climate Change

JI: Joint Implementation

LS: Least Square

MCA: Multi Criteria Analysis

PRC: The People's Republic of China

SCE: Standard Coal Equivalent

TOR: Trade Openness Ratio

UN: United Nations

UNFCCC: United Nations Framework Convention on Climate Change

VAT: Value Added Tax

VERs: Voluntary Emissions Reductions

List of Appended Papers

Paper I

Xu, B., Sun, Q., Wennersten, R. & Brandt, N., 2010. An Analysis of Chinese Policy Instruments for Climate Change Mitigation. *International Journal of Climate Change Strategies and Management* 2 (4): 380-392.

Paper II

Sun, Q., Xu, B., Wennersten, R. & Brandt, N., 2010. Co-benefits of CDM Projects and Policy Implications. *Environmental Economics* 1 (2): 78-88.

Paper III

Xu, B., Sun, Q., Wennersten, R. & Brandt, N., 2011. An analysis of China's carbon dioxide mitigation target. *Sustainable Development (Accepted).*

Paper IV

Xu, B., Wennersten, R. & Brandt, N., 2011. A projected turning point of China's CO_2 emissions – an analysis of Environmental Kuznets Curve for China. *Special Issue of Global Warming perspectives and new solutions, in the "International Journal of Global Warming" (submitted for publication).*

Paper V

Sun, Q., Yang, Q., Xu, B., Wennersten, R. & Brandt, N., 2010. Sustainability of CDM projects – An experimental study using AHP. In *the 2010 Gordon Research Conference on Industrial Ecology (GRS).* July 11-16, 2010, New London, NH, USA.

Table of Contents

1 Introduction

1.1 Background

Emissions of greenhouse gases (GHGs) world-wide increased by over 70% (from 28.7 to 49.0 billion tonnes of carbon dioxide equivalents (CO_2e)) in the period 1970-2004, with CO_2 being the most significant contributor, having grown by about 80% during the period (IPCC, 2007). Therefore, mitigation of climate change, especially CO_2 emissions, is important to avoid long-term irreversible climate change and its devastating consequences (IPCC, 2007). The greatest effort on climate change mitigation to date is the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), which defines binding targets for industrialised countries in Annex B (Annex B countries) in terms of limiting and/or reducing their GHG emissions for the period 2008 to 2012 in comparison with the base year 1990 (UNFCCC, 1998). In addition, the Kyoto Protocol highlights the principle of 'common but differentiated responsibilities', which acts as the foundation of international cooperation on climate change.

China has experienced great economic development and fast urbanisation since the reform and opening up policy was launched in 1978. However, these achievements are reliant on primary energy consumption, mainly fossil fuels, characterised by high pollution and low efficiency (Crompton and Wu, 2005; Haberl et al., 2011; Heggelund and Buan, 2009; National Development and Reform Commission, 2009). Due to the rapid growth in primary energy consumption, with coal representing about 70% of the total (National Bureau of Statistics of China, 2010), China's GHG emissions have also been increasing very rapidly since 1978. A number of studies show that China has overtaken the USA and is now the largest emitter of CO_2 in the world, although China's historical cumulative emissions still remain low, especially on the per capita level (Gregg et al., 2008; Guan et al., 2009; Han et al., 2004; IEA, 2010; National Bureau of Statistics of China, 2010; Oberheitmann, 2010; The Netherlands Environmental Assessment Agency, 2007). Following the principle of common but differentiated responsibilities, China does not need to undertake any limitation or reduction commitment in the Kyoto Protocol's first commitment period 2008-2012. However, the exponential growth in China's GHG emissions has been heavily condemned in recent international negotiations on climate change mitigation (Heggelund, 2007).

Responding to both domestic challenges and international pressure regarding energy, climate change and environment, since the early 2000s the Chinese government has made a point of addressing climate change (for a review of policy instruments see Paper I). Regarding climate change mitigation, the Chinese government has emphasised that any mitigation strategy must consider China's domestic economic development and thus defined national mitigation targets based on intensity indicators. In its *11th Five-Year Social and Economic Development Programme (2006-2010)*, the Chinese government decided to decrease national energy intensity (end-use energy consumption per unit of gross domestic product, EC/GDP) by 20% in 2010 compared with the 2005 level (Ministry of Environmental Protection of the People's Republic of China, 2008). This target was met in 2010, according to Li Yizhong, the former Minister of Industry and Information Technology of China (Xinhua, 2010). Before the Copenhagen Summit (COP15) in 2009, the Chinese government announced a more straightforward mitigation strategy, i.e. to reduce CO_2 emissions per unit of GDP (CO_2/GDP) by 40-45% by 2020 compared with the 2005's level (Fu et al., 2009). At the COP15, the Chinese Prime Minister further emphasised that the mitigation target would be pursued without referring to any other countries or relating to any other conditions (see Paper III).

In recent years, the Chinese government has adopted a number of policy instruments for mitigating climate change. These mainly consist of regulation-based instruments, namely administration instruments and technological improvement regulations, and economic instruments such as designated fuel prices, flexible electricity tariffs and funds for reducing emissions of CO_2 and other pollutants (see Paper I). While these instruments had been considered useful in achieving the target in terms of energy intensity by 2010, carbon taxes and emissions trading schemes, among others, are often proposed for inclusion in the current policy system in order to improve the cost-effectiveness of climate change mitigation.

In addition to domestic effects, China has been actively participating in international cooperation for mitigating climate change. Following the principle of common but differentiated responsibilities, China does not need to undertake any limitation or reduction commitment in the Kyoto Protocol's first commitment period before 2012. A major way for China to participate in international climate change mitigation is by providing certified emissions reductions (CERs) for the Annex B countries under the Clean Development Mechanism (CDM). Currently, China's CDM projects play an important role in maintaining the international carbon price at a low level and the amount of CERs generated by China's CDM had already reached over 50% of the entire mitigation commitments of industrialised countries by the end of 2010 and was continuing to grow before 2012 (Sun, 2011). In addition, China joined the Asia-Pacific Partnership on Clean Development and Climate (APP) in 2005, which represents voluntary public-private partnerships from the United Nations (UN) system and aims to reduce GHG emissions by implementation of cleaner technology (Heggelund and Buan, 2009).

Being the world's largest emitter of CO_2 emissions and having influence in the Group of 77 (G77) of Third World states and the UN, China is playing a prominent role in the present climate regime, and this will not change in the post-2012 period (Grubb, 2010; Heggelund, 2007). Therefore, it is very important to study the history and future trend of China's CO_2 emissions and to understand China's attitudes toward international cooperation regarding mitigation.

1.2 Aim, objectives and methodology

The aim of this thesis was to comprehensively study China's CO_2 emissions and policy instruments for mitigating climate change. To achieve the overall aim, specific objectives established were to:

- Review China's CO_2 emissions in the past three decades and examine the Environmental Kuznets Curve (EKC) hypothesis
- Evaluate China's mitigation target compared with business-as-usual (BAU) scenarios
- Study policy instruments for mitigating climate change in China.

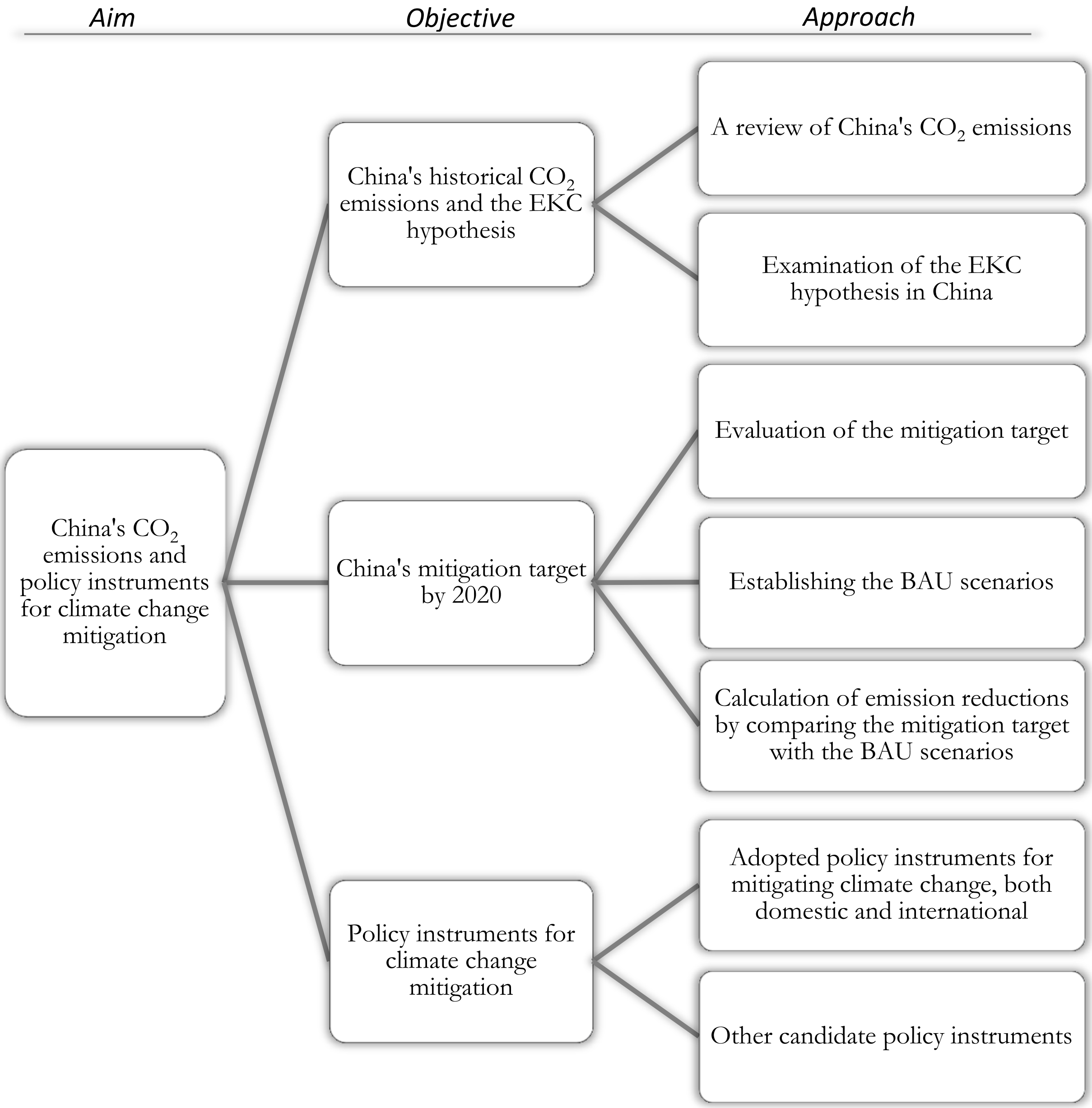

Figure 1-1 Overall methodology adopted in the thesis

The overall methodology adopted in the thesis is shown in Figure 1-1 and the approaches to achieve the specific objectives are described below.

- Reviewing China's historical CO_2 emissions

To achieve this objective, China's overall CO_2 emissions in the period 1978-2008 were first reviewed. Important macroeconomic factors, namely population, GDP, energy consumption and the openness ratio of China's economy, and their impacts on CO_2 emissions in the period were also analysed.

- Examining the EKC hypothesis in China

The EKC hypothesis was examined using empirical data on China for the past three decades. A popular natural logarithmic quadratic model, which considers those important macroeconomic factors previously reviewed, was applied in the examination.

- Evaluating China's emissions reductions according to the mitigation target

To achieve this objective, China's CO_2 emissions by 2020 were evaluated, assuming that the present mitigation target, i.e. to reduce CO_2 emissions per unit of GDP by 40-45% by 2020 compared with the 2005 level, would be met. Three BAU scenarios were then developed and compared with the level of emissions according to the mitigation target in order to calculate possible reductions needed to reach the target.

- Studying the policy instruments for climate change mitigation in China

To achieve this objective, policy instruments adopted by the Chinese government for mitigating climate change, including both domestic measures and participation in international cooperation, were reviewed and analysed. Domestic measures consist of regulation-based instruments and economic instruments, while the main way for China to participate in international cooperation regarding climate change mitigation is by supplying CERs to industrialised countries under the CDM system. Other candidate policy instruments, especially those considered economically effective, i.e. carbon taxes and emissions trading, were also introduced and discussed.

1.3 Introduction to Papers I-V

This thesis is based on five published (or accepted) papers. These are briefly introduced and a summary of their contribution is provided below.

Paper I

Xu, B., Sun, Q., Wennersten, R. & Brandt, N., 2010. An Analysis of Chinese Policy Instruments for Climate Change Mitigation. *International Journal of Climate Change Strategies and Management* 2 (4): 380-392.

Paper I analyses the policy instruments adopted by the Chinese government for mitigating climate change before 2010. Reducing energy intensity (EC/GDP) was the main focus of policy design regarding climate change at that stage. In order to determine the effectiveness of policy instruments, China's energy intensity of economic output was reviewed, categories of policy instruments were examined and compared, and the specific situations in two provinces were analysed. The main findings of the study were that: (1) Energy intensity had declined, indicating the importance and effectiveness of the policy instruments in general; (2) technological improvement regulations had made the greatest contribution to achieving the mitigation target regarding energy intensity; and (3) general instruments on the national level but also quite a few specially designed instruments had been adopted to achieve the provincial mitigation tasks, which were distributed from the national target. Paper I contributes to the discussion on policy instruments for mitigating climate change in China, especially in the early stage when the mitigation target was based on energy intensity rather than a reduction in carbon dioxide levels. My contribution to the paper was to organise the overall structure of the study, collect materials from Chinese official administrations and draw conclusions from the main findings.

Paper II

Sun, Q., Xu, B., Wennersten, R. & Brandt, N., 2010. Co-benefits of CDM Projects and Policy Implications. *Environmental Economics* 1 (2): 78-88.

Paper II examines China's CDM projects and especially concentrates on the co-benefits generated by these projects and their policy implications. The study found that CDM to date represents the major way for China to participate in international cooperation on climate change mitigation, and that CDM projects are important not only for industrialised countries but also for developing countries themselves. Although a large amount of co-benefits could be generated from energy-related CDM projects, the study suggested that the values of co-benefits should not be involved in current international negotiations or used to ensure the contribution of CDM to sustainable development. However, co-benefit analysis can benefit local government in developing countries by indicating synergies or optimised trade-offs between climate change mitigation and environment protection. My main contribution to Paper II was to provide part of the discussion on policy instruments in terms of China's participation in international cooperation on climate change mitigation.

Paper III

Xu, B., Sun, Q., Wennersten, R. & Brandt, N., 2011. An analysis of China's carbon dioxide mitigation target. *Sustainable Development (Accepted).*

Paper III examines China's first mitigation target relating to CO_2 emissions, i.e. to reduce CO_2 emissions per unit GDP by 40-45% by 2020 compared with the 2005 level. In order to transfer the mitigation target from emissions intensity to absolute emissions, several scenarios at different GDP growth rates, in which the mitigation target was to be met, were developed and compared with the business-as-usual scenarios. The results showed that the total amount of CO_2 emissions to reach the intensity target will have to be significantly reduced compared with the business-as-usual scenarios. However, an increase in absolute CO_2 emissions could not be avoided due to the economic growth. In this study, a linear regression, rather than a quadratic regression, was used to forecast China's future CO_2 emissions, since the quadratic regression provides an unrealistic turning point in the emissions trajectory. The study provides an important basis for examining China's present target of climate change mitigation. In addition, the concerns about an EKC relationship between CO_2 emissions per capita and GDP per capita are further discussed in Paper IV. My contribution to Paper III was to address the aim, objectives and method and to review the relevant literature on China and on other countries.

Paper IV

Xu, B., Wennersten, R. & Brandt, N., 2011. A projected turning point of China's CO_2 emissions – an analysis of Environmental Kuznets Curve for China. *Special Issue of Global Warming Perspectives and New Solutions, in the International Journal of Global Warming (submitted for publication).*

Paper IV examines the existence of an EKC relationship between CO_2 emissions per capita and GDP per capita in China in the period 1980-2008. A natural logarithm-quadratic relationship was found in the regression, which supported the EKC hypothesis regarding CO_2 emissions in China.

However, China's CO_2 emissions are still on a growing track until around 2078 in the empirical analysis. More importantly, CO_2 emissions will not spontaneously decrease if China continues to develop its economy without adopting instruments for mitigating climate change. Important factors which were not considered in the regression include the wealth gap in China and its role in international trade. Based on this study, the thesis developed the regression model by simultaneously considering the impacts of primary energy consumption and international trade on CO_2 emissions. I contributed the idea, method and organised the structure of Paper IV.

Paper V

Sun, Q., Yang, Q., Xu, B., Wennersten, R. & Brandt, N., 2010. Sustainability of CDM projects - An experimental study using AHP. In *The 2010 Gordon Research Conference on Industrial Ecology (GRS)*. July 11-16, 2010, New London, NH, USA.

Paper V compares two CDM projects, a hydropower and a HFC23 decomposition project, in terms of their impacts on sustainable development, using the Analytic Hierarchy Process (AHP) method, which is a theory of measurement through pairwise comparisons to represent how much one element dominates over another with respect to a given impact. Two groups of post-graduate students performed the experimental assessment and both groups found that the HFC23 decomposition project is a larger contributor to sustainable development than the hydropower project. In addition, discussion on the pros and cons of the AHP method revealed that participation of local stakeholders in assessment of CDM projects regarding sustainable development is necessary. Together with Paper II, the study provides a basis for the discussion on the role of CDM in developing countries. In addition, Papers II and V indirectly highlight the importance of synthesising international cooperation with domestic policies when it comes to the discussion on climate change mitigation and sustainable development. My main contribution to Paper V was to discuss the AHP method (features and weakness) and collect data.

1.4 Structure of the thesis

The remainder of this thesis is organised into the following five chapters:

- Chapter 2: China's CO_2 emissions and the EKC hypothesis

China's historical CO_2 emissions in the period 1978-2008 are reviewed and the impacts of a number of important macroeconomic factors on these emissions are discussed. The EKC hypothesis is then examined using empirical data on China for the past three decades.

- Chapter 3: China's CO_2 mitigation target by 2020

Responding to international and domestic pressure and attempting to present a responsible image in international affairs, the Chinese government announced a straightforward mitigation target, i.e. to reduce CO_2 intensity of GDP by 40-45% by 2020 compared with the 2005 level. Chapter 3 analyses this mitigation target, specifically by evaluating the magnitude of the CO_2 emissions reduction if the target were to be met by 2020.

- Chapter 4: Policy instruments for climate change mitigation in China

Policy instruments for climate change mitigation in China, namely domestic policy instruments, participation in international cooperation and other candidate policy instruments, are described and analysed.

- Chapter 5: Discussion

The results from previous chapters are discussed.

- Chapter 6: Conclusions

Conclusions are drawn from the main findings. Finally, some thoughts on China's mitigation efforts are presented.

2 China's CO_2 emissions and the EKC hypothesis

In this chapter, China's historical CO_2 emissions in the period 1978-2008 are reviewed and the impacts of several important macroeconomic factors, i.e. population, GDP, primary energy consumption, openness ratio of China's economy, on the emissions are discussed. The EKC hypothesis is then examined using empirical data on China for the past three decades, with important macroeconomic factors being considered in the examination.

2.1 China's CO_2 emissions in the period 1978-2008

China's economy has been rapidly developing since the reform and opening up policy was launched in 1978, while China's energy consumption and CO_2 emissions have been following a similar increasing trend as the economy, as shown in Figure 2-1. Note that energy consumption refers to consumption of primary energy in this study and it consists of coal, crude oil, natural gas hydropower, wind power and nuclear according to China Statistical Yearbook (National Bureau of Statistics of China, 2010; National Bureau of Statistics of China, 2011a).

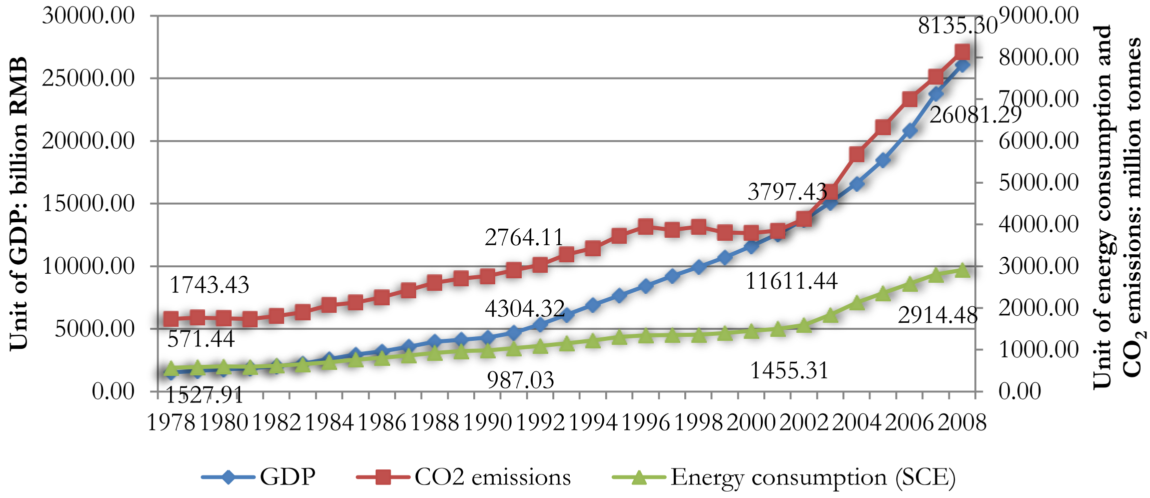

Figure 2-1 China's GDP, energy consumption and CO_2 emissions, 1978-2008
Source: calculated from National Bureau of Statistics of China (2010); and IEA (2010).

While China's GDP increased from 1527.91 billion RMB to 26081.29 billion RMB in the period 1978-2008, representing an increase of 9.92% per annum, primary energy consumption, measured as standard coal equivalents (SCE), increased from 571.44 million tonnes to 2914.48 million tonnes and CO_2 emissions increased from 1743.43 to 8135.30 million tonnes in the same period, an increase rate of 5.58% and 5.27% per annum, respectively (Figure 2-1). Note that the data on China's GDP were real GDP and adjusted to 2005 prices, and Hong Kong, Macao and Taiwan were not included in this figure or elsewhere. In addition, the data on China's CO_2 emissions were calculated from the International Energy Agency (IEA) energy balance statistics. IEA energy balance statistics focus on energy-related CO_2 emissions, but do not consider the CO_2 emissions from non-energy-related sources and gas flaring (IEA, 2010). Energy-related emissions in turn account for about 80% of total GHG emissions globally (UNFCCC, 2010). In addition, the average ratio for the IEA's estimates in 1990-2008 was 78.83% of total GHG emissions, a figure obtained by comparing the aggregated IEA data for all industrialised countries with their total emissions in the national emissions inventories submitted to the UNFCCC (Sun, 2011). Therefore, China's total CO_2 emissions were calculated in this thesis by enlarging the IEA figures using a factor of 80%.

As shown in Figure 2-1, the growth trends for China's economy, primary energy consumption and CO_2 emissions in the past three decades, all increased significantly during the period. An important reason is that the growth of China's economy in that period, achieved through urbanisation and industrialisation, depended heavily on primary energy consumption, which increased continuously and was often characterised by high pollution and low efficiency (Crompton and Wu, 2005; Haberl et al., 2011; National Development and Reform Commission, 2009; Xu et al., 2010). Another reason is that the structure of China's primary energy consumption has so far not been significantly changed (Figure 2-2). While renewable energy and nuclear power together contributed to less than 10% of China's primary energy consumption, as seen in Figure 2-2, fossil fuels accounted for the dominant share, e.g. with coal alone accounting for approximately 70% of the total primary energy consumption in the past thirty years.

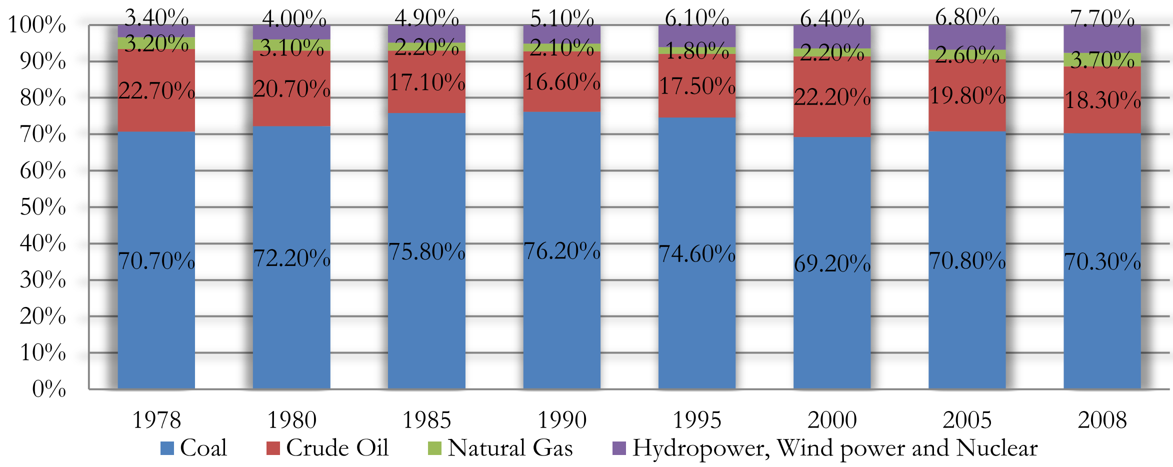

Figure 2-2 Structure of primary energy consumption in China, 1978-2008
Source: National Bureau of Statistics of China (2010).

In addition to the economy and primary energy consumption, population and trade openness are often considered important factors affecting CO_2 emissions (Guan et al., 2008; Guan et al., 2009; Weber et al., 2008; Zhu et al., 2006). Following the principle of 'common but differentiated responsibilities', a fair distribution of emissions rights and mitigation responsibilities lies at the midpoint of international negotiations. There are several approaches being discussed, including: (1) Per capita convergence in emission endowments; (2) soft-landing in emissions growth; (3) global preference score approach; (4) historical contribution to climate change or 'Brazilian proposal'; (5) ability to pay; and (6) multi-stage approach (CNRS/LEPII-EPE et al., 2003). In general, approaches 1-3 belong to a full participation regime, i.e. a set of rules or targets that define how the emissions quotas of all parties develop over a long period, while approaches 4-6 represent a multi-stage regime, where the climate regime is gradually expanded to include more countries with binding quantified emissions limitation or reduction objectives, whether absolute or dynamic (Oberheitmann, 2010). In general, how 'fairness' is defined differs between these approaches and it has so far not been agreed by different countries. Nevertheless, a basic principle of 'fairness' is that each human being has an equal right to use the atmosphere.

Therefore, distributing emissions rights and mitigation responsibilities to a country must consider its population. Although China has the largest amount of CO_2 emissions in the world at present, its per capita CO_2 emissions still remain a low level, especially on the historical cumulative level, a principle suggested and insisted on by the Chinese government to allocate emissions rights and mitigation responsibilities (Gregg et al., 2008; Guan et al., 2009; Oberheitmann, 2010; The Netherlands Environmental Assessment Agency, 2007). However, China's per capita CO_2 emissions are increasing very rapidly, due to the rapid growth in emissions and to the relatively slow increase in population, i.e. the average increase in China's population was only 1.08% per annum in the period 1978-2008 as a result of the controversial family planning policy (Ding and Hesketh, 2006; National Bureau of Statistics of China, 2011a; Rajeswar, 2000). Hence, China must take proactive measures to limit the growth in CO_2 emissions as soon as possible before these eventually become too cumbersome to mitigate, even if emissions rights and mitigation responsibilities are distributed on an individual basis.

International trade may be another important factor affecting a country's CO_2 emissions. Figure 2-3 shows China's international trade in the period 1980-2008. As can be seen, both exports and imports have been growing strongly, especially since 2000. The total amount of international trade (the amount of exports plus imports) increased from 57.00 billion RMB in 1980 to 17992.15 billion RMB in 2008. Meanwhile, China's exports have surpassed imports since 1994 and the amount of net exports, i.e. exports over imports (green line in Figure 2-3), has increased tremendously in recent years, from 266.75 billion RMB in 2004 to 2086.84 billion RMB in 2008 (Figure 2-3).

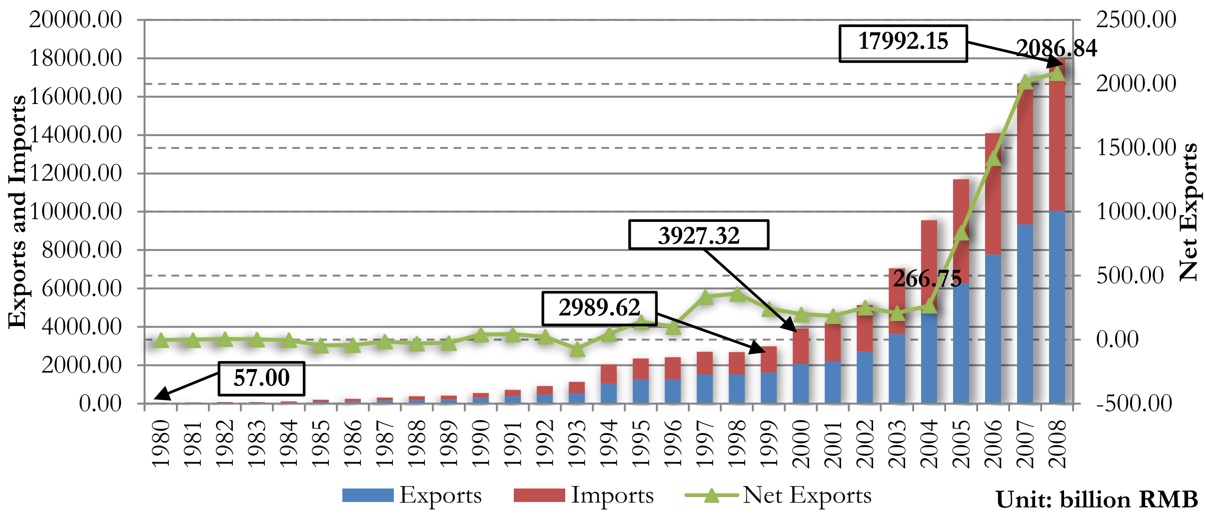

Figure 2-3 China's international trade, 1980-2008

Source: National Bureau of Statistics of China (2011b).
Note: Data for before 1980 were unavailable.

To examine the impacts of international trade on CO_2 emissions, Guan et al. (2008) analysed China's exports in the period 1980-2006 using Input-Output Analysis and concluded that the growth in exports was the main driver of the increase in China's CO_2 emissions. Weber et al. (2008) examined the CO_2 emissions produced by Chinese exports and found that about one-third of China's CO_2 emissions came from the manufacturing processes relating to exports. These findings raise concerns about who should be responsible for the CO_2 emissions relating to China's exports, namely China as the producer or the other countries who ultimately consume the products. Weber et al. (2008) suggested that current international trade is likely to be driven by developed countries on the demand side, due to a buyer's market. However, should China correspondingly be responsible for the CO_2 emissions relating to its imports? To answer this question, Wang and Watson (2007) examined the CO_2 emissions associated with China's net exports and found that these accounted for about 23% of China's total CO_2 emissions in 2004. This figure could have become even larger in recent years due to the dramatic increase in net exports since 2004 (Figure 2-3), and also due to the relatively high level of carbon intensity in China's economy (Wang and Watson, 2007). Trade openness ratio is introduced in the following study and defined as the ratio of the total value of imports and exports to the value of GDP.

2.2 Empirical study of the EKC hypothesis

Comprehensively considering the relationship between environmental problems and economic growth, many studies refer to the EKC hypothesis, which states that environmental degradation is aggravated as the economy grows in its initial stages, and that environmental degradation begins to decline once the economy reaches a certain level (Dinda, 2004; Stern, 2004; Yuan et al., 2007). The reasons relate to improvements in technology and public willingness to protect the environment and human health, which are achieved as the economy develops (Atici, 2009). Previous studies have verified the EKC hypothesis mostly in terms of SO_2 emissions, i.e. SO_2 emissions per capita follow an inverted U-shaped curve as GDP per capita grows (Heil and Selden, 2001). Although recent literature, e.g. Jalil and Mahmud (2009), also reported similar results on the EKC hypothesis for CO_2 emissions, there has been no consensus on this issue to date, especially in different countries. For example, Du et al. (2007) found that the trend in China's CO_2 emissions per capita follows a N-shaped curve, rather than an inverted U-shaped curve. Song et al. (2008) suggested that there can be seven different forms of environmental-economic relationships and a N-shaped and an inverted U-shaped curve are just two of these. On comparing 165 countries, Han and Lu (2009) argued that the EKC hypothesis does not apply to all countries and that in the countries with a low level of income and a relatively high level of industrialisation, such as China, the growth in the economy and in CO_2 emissions often occurs simultaneously.

The validity of the EKC hypothesis is often tested by a linear natural logarithmic-quadratic model, which describes the long-term relationship between CO_2 emissions and their impact factors (Ang, 2007; Atici, 2009; Auffhammer and Carson, 2008; Halicioglu, 2009; Jalil and Mahmud, 2009). This thesis adopted the same method to test the EKC hypothesis in China, using empirical data for the period 1980-2008. Specifically, the linear logarithmic-quadratic model in terms of total CO_2 emissions per capita (CPC) regarding GDP per capita (GPC), primary energy consumption per capita (ECPC) and trade openness ratio (TOR) was developed as Equation 2-1.

$$\ln CPC_t = \beta_1 + \beta_2 ln\, GPC_t + \beta_3 (ln\, GPC_t)^2 + \beta_4 ln\, ECPC_t + \beta_5 ln\, TOR_t + \varepsilon_t \qquad (2-1)$$

where:

- ε is the regression error term
- t is year from 1980 to 2008

- β_1 is a constant value
- β_2 is the elasticity coefficient for lnGPC
- β_3 is the elasticity coefficient for $(\text{lnGPC})^2$
- β_4 is the elasticity coefficient for lnECPC
- β_5 is the elasticity coefficients for lnTOR.

If the EKC hypothesis of an inverted U-shape holds, β_2 should be positive; β_3 should be negative; β_4 is expected to be positive in a common sense because an increase in primary energy consumption should result in an increase in CO_2 emissions when there have not been significant improvements in energy technology (Ang, 2007; Atici, 2009); and β_5 is expected to be negative in China because China had net exports in most years from 1980 to 2008 (Figure 2-3) and China's exports were generally more energy-intensive than its imports (Guan et al., 2008; Halicioglu, 2009).

The cointegration, i.e. the long-term relationship, between CO_2 emissions and impact factors, was examined in the following two steps:

Step 1 The stationarity of variables was verified in order to avoid spurious regression (Chen and Liu, 2004; Soytas et al., 2007):

1) if the variables are stationary, Step 2 can be carried out; or

2) if the variables are not stationary, Step 2 can still be carried out when the differences in the variables of the same order are stationary (as was the case in this study, see Section 2.2.1 for details);

3) otherwise, Step 2 cannot be carried out and this means CPC and the other variables cannot be cointegrated.

Step 2 The Engle-Granger method (Engle and Granger, 1987) was applied to the cointegration analysis and this included:

1) the coefficients $(\beta_1, \beta_2, \beta_3, \beta_4, \beta_5)$ were estimated using the Least Square (LS) method, and then

2) the residuals obtained from the regression were examined to determine whether the coefficients were meaningful.

Note that if the residuals are not stationary, there is no long-term relationship between CPC and the other variables, or CPC is not cointegrated with the other variables.

2.2.1 Stationarity of variables

In order to facilitate the regression, Equation (2-1) was written as:

$$y_t = \beta_1(x_1)_t + \beta_2(x_2)_t + \beta_3(x_3)_t + \beta_4(x_4)_t + \beta_5(x_5)_t + \varepsilon_t \qquad (2-2)$$

where y is $\ln \mathrm{CPC}$; x_1 is 1; x_2 is $\ln \mathrm{GPC}$; x_3 is $(\ln \mathrm{GPC})^2$; x_4 is $\ln \mathrm{ECPC}$; x_5 is $\ln \mathrm{TOR}$; and ε is an regression error term. The stationarity of variables was verified using the Augmented Dickey-Fuller (ADF) unit root test method, and the calculation was made using *Eviews 5.0*.

Table 2-1 ADF unit root test of y, x_2, x_3, x_4 and x_5

Null Hypothesis: *y*, x_2, x_3, x_4 and x_5 have a unit root		
Exogenous: Constant		
	ADF test statistic	Test critical values
y	0.011299	-2.627420*
x_2	-0.448039	-2.642242*
x_3	1.847154	-2.635542*
x_4	1.360692	-2.638752*
x_5	-1.706201	-2.625121*

Notes: The LS method was used in the ADF unit root test; the maximum number of lags was set to six; * represents 10% level of significance.

As shown in Table 2-1, the null hypothesis was rejected for all variables, i.e. the absolute values of the ADF test statistical values were smaller than the absolute values of the test critical values, which means that all variables are not stationary at the 10% level of significance. Therefore, the first order differences of each variable were calculated and examined in the stationarity test.

Table 2-2 ADF unit root test of $D(y)$, $D(x_2)$, $D(x_3)$, $D(x_4)$ and $D(x_5)$

Null Hypothesis: *D(y)*, $D(x_2)$, $D(x_3)$, $D(x_4)$ and $D(x_5)$ have a unit root		
Exogenous: Constant		
	ADF test statistic	Test critical values
D(y)	-2.639827	-2.627420*
$D(x_2)$	-3.887350	-3.737853***
$D(x_3)$	-2.938401	-2.635542*
$D(x_4)$	-3.038738	-2.998064**
$D(x_5)$	-4.514928	-3.699871***

Notes: The LS method was used in the ADF unit root test; the maximum number of lags was set to six; *, **, *** represent the 10%, 5% and 1% level of significance, respectively.

The first order differences of each variable were stationary at the 10% level of significance, i.e. the absolute values of the ADF test statistical values were larger than the absolute values of the test critical values (Table 2-2). Therefore, the cointegration analysis was carried out using the Engle-Granger method (Engle and Granger, 1987).

2.2.2 Cointegration analysis

The LS method was applied to the regression of Equation 2-2 to estimate the coefficients and the results are shown in Table 2-3.

Table 2-3 Results of regression

Dependent Variable: y				
Method: Least Squares				
Sample: 1980 2008				
Variable	Coefficient (β)	Std. Error	t-Statistic	Prob.
x_2	0.6924	0.237136	2.919764	0.0075
x_3	-0.0459	0.014349	-3.201483	0.0038
x_4	1.4008	0.099343	14.10037	0.0000
x_5	-0.1770	0.048334	-3.662072	0.0012
Intercept (x_1)	-4.4647	1.589039	-2.950054	0.0070
R-squared	0.996190			

Therefore, the cointegration of the linear natural logarithmic-quadratic model was estimated as:

$$y_t = -4.4647 + 0.6924(x_2)_t - 0.0459(x_3)_t + 1.4008(x_4)_t - 0.1770(x_5)_t \qquad (2-3)$$

Table 2-4 ADF unit root test of residuals

Null Hypothesis: The series of residuals has a unit root			
Exogenous: Constant			
Method: Least Squares			
Dependent Variable: D(residuals)			
Sample: 1980 2008			
No. of observations included: 29			
		t-Statistic	**Prob.**
ADF test statistic		-2.963384	0.0509
Test critical values:	1% level	-3.689194	
	5% level	-2.971853	
	10% level	-2.625121	

The residuals obtained in Equation 2-3 were then examined using the ADF unit root test and the results are shown in Table 2-4. As can be seen in Table 2-4, the absolute value of the test critical values was smaller than the absolute value of the ADF unit root test statistic value at the 10% level of significance, so that the null hypothesis is rejected, which means that the residuals are stationary at the 10% level of significance. Therefore, a cointegration relationship exists betweenx_2, x_3, x_4, x_5 and y, and the coefficients ($\beta_2, \beta_3, \beta_4\ and\ \beta_5$) in the cointegration are meaningful. In addition, the values of the coefficients are congruent with the above analysis, namely $\beta_2 > 0$, $\beta_3 < 0$, $\beta_4 > 0$, and $\beta_5 < 0$ which is evidence to support the EKC hypothesis.

2.2.3 Empirical analysis

The EKC hypothesis indicates that the stationary point of CPC to the factor of GPC will appear when the GPC reaches the level of $exp|\beta_2/2\beta_3|$, i.e. 1874 RMB according to Equation 2-3. Considering the value in practice, China's GPC was 1864 RMB in 1981 and reached 2001 RMB in 1982 (Figure 2-4), and this means that the stationary point was attained in 1982.

The verification of the EKC hypothesis and the attainment of the stationary point indicate that the growth in GDP has become a declining force for CO_2 emissions after 1982. However, China's CO_2 emissions will continue to increase in the coming decades. The reasons include that

CO_2 emissions are simultaneously affected by factors other than GDP, such as primary energy consumption and international trade, which will continue to grow. Given that the coefficients in the linear logarithmic-quadratic model demonstrate the elasticity of CO_2 emissions per capita (Chen and Zhang, 2008; Granger, 1986), the impacts of primary energy consumption on CO_2 emissions are greater than GDP, i.e. CO_2 emissions will increase by around 1.4% when primary energy consumption increases by 1%, while emissions will increase by less than around 0.69%, or even decrease, when GDP increases by 1% (Equation 2-3).

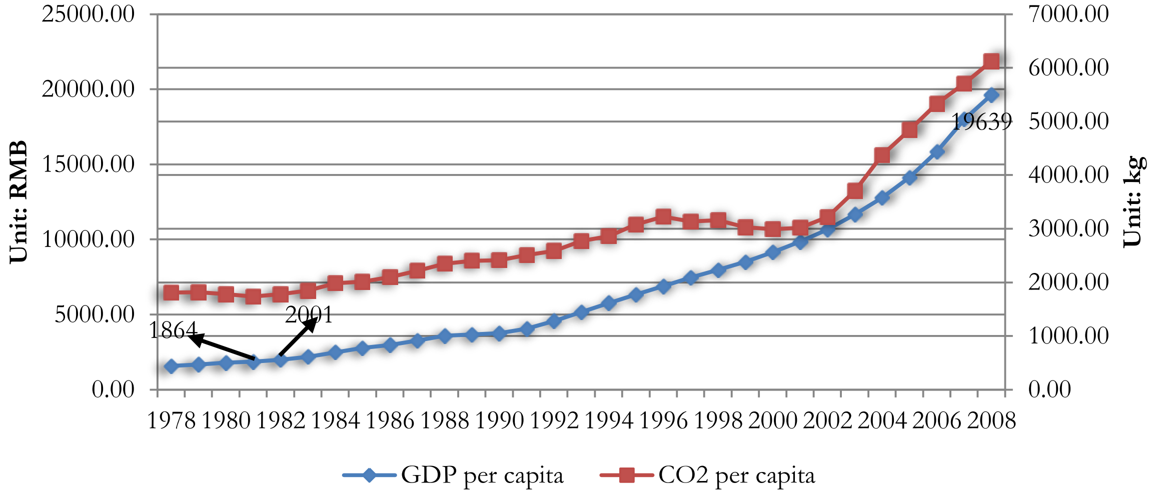

Figure 2-4 China's GDP per capita and CO_2 per capita, 1978-2008
Source: National Bureau of Statistics of China (2010); and IEA (2010).

The turning point of overall CPC to the factors of GPC, ECPC and TOR was then estimated further. In order to give a rough sense of the turning point, a projection was carried out in this study. To simplify calculations, it was assumed that: (1) The growth in GDP is 10% per annum; (2) population and energy consumption will increase at the same speed as their average levels in the past; and (3) TOR will remain at the average level which is 54%. As shown in Figure 2-5, China's CO_2 emissions will continue to grow over a very long period and the turning point in overall CO_2 emissions will appear at 37365 million tonnes in 2078. It should be noted that the turning point will be reached later than 2078 when the growth in GDP is slower than 10% per annum, since growth in GDP is a declining force for CO_2 emissions according to the EKC hypothesis.

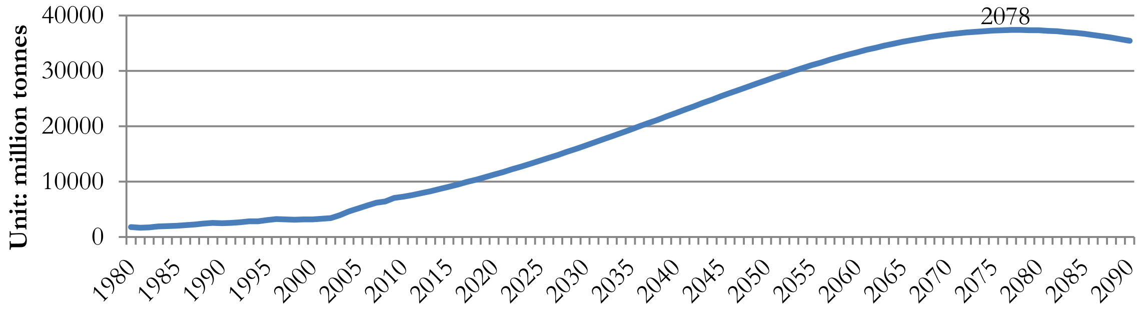

Figure 2-5 Turning point in China's CO_2 emissions
Source: National Bureau of Statistics of China (2011b); and IEA (2010).

Comparing the results with other studies, most studies found that China's CO_2 emissions and GDP can be cointegrated, in other words there is a long-term relationship between CO_2 emissions and GDP (Han and Lu, 2009; Jalil and Mahmud, 2009; Wang et al., 2011; Yaguchi et al., 2007). However, whether the EKC hypothesis is true, and especially when the turning point appears when the EKC hypothesis is verified, remain debatable and the answers highly dependent on the impact factors and/or data used (Dinda, 2004; Stern, 2004). Using the most frequently studied macroeconomic factors and time-series data for the period 1980-2008, this study found the existence of an EKC relationship between CO_2 emissions per capita and GDP per capita. It should be noted that to date, there have been only a little more than three decades since the reform and opening up policy was launched in China and from an econometrics perspective, the regression to verify the EKC hypothesis could be more stable if a longer period of statistical data were available. In addition, different results are produced when panel data are adopted, e.g. Yaguchi et al. (2007) and Wang et al. (2011).

Another common finding is that China's CO_2 emissions are still on a growing track, even if the EKC hypothesis has been verified, as shown above (Figure 2-5). However, the analysis of the EKC hypothesis only concerns the statistical relationship between empirical CO_2 emissions and their impact factors in principle, rather than a fundamental theorem predicting a fact that will occur regardless. This means that the relationship based on data in the past can be changed and a new relationship can be established when new statistics are available. More importantly, CO_2 emissions will not spontaneously decrease if China continues to develop its economy without mitigating climate change. However, CO_2 emissions could start to decrease if substantial efforts are made, e.g. decoupling primary energy consumption from economic growth and improving energy efficiency in such a way that less CO_2 emissions will be generated per unit of primary energy consumption.

3 China's CO_2 mitigation target by 2020

As mentioned earlier, developing countries do not have to undertake any obligatory mitigation commitments in the first commitment period of the Kyoto Protocol between 2008 and 2012. However, responding to international and domestic pressure and attempting to present a responsible image in international affairs, the Chinese government announced a mitigation target before the Copenhagen Summit in 2009, i.e. to reduce CO_2 intensity of GDP by 40-45% by 2020 compared with the 2005 level. This chapter analyses this mitigation target, namely by evaluating the magnitude of the CO_2 emissions that would have to be avoided if the target were to be met by 2020. To achieve this objective, the emissions in the period 2009-2020 were calculated, assuming that the target would be met; three BAU scenarios were developed and the emissions in the BAU scenarios were estimated; and the magnitude of CO_2 emissions that would have to be avoided to achieve the target were then calculated by comparing the emissions according to the mitigation target with the BAU scenarios.

3.1 China's CO_2 emissions according to the mitigation target

To determine the mitigation target, the CO_2 intensity in the period 1978-2008 was reviewed (Figure 3-1). Note that the values shown in Figure 3-1 were calculated by enlarging the IEA figures using a factor of 80% (for more explanation, see Chapter 2). As can be seen in the diagram, China's CO_2 intensity decreased from 1141.05 tonnes per million RMB in 1978 to 311.92 tonnes per million RMB in 2008, representing a great improvement in general. The lowest level of CO_2 intensity was found in 2002 and the value has been relatively stable since then. In 2005, the CO_2 intensity was 342.52 tonnes per million RMB, which means that the CO_2 intensity has to decline to 188.39-205.51 tonnes per million RMB in 2020 in order to meet the target. Note that the calculations in this chapter were based on the values of real GDP, which was adjusted to 2005 prices.

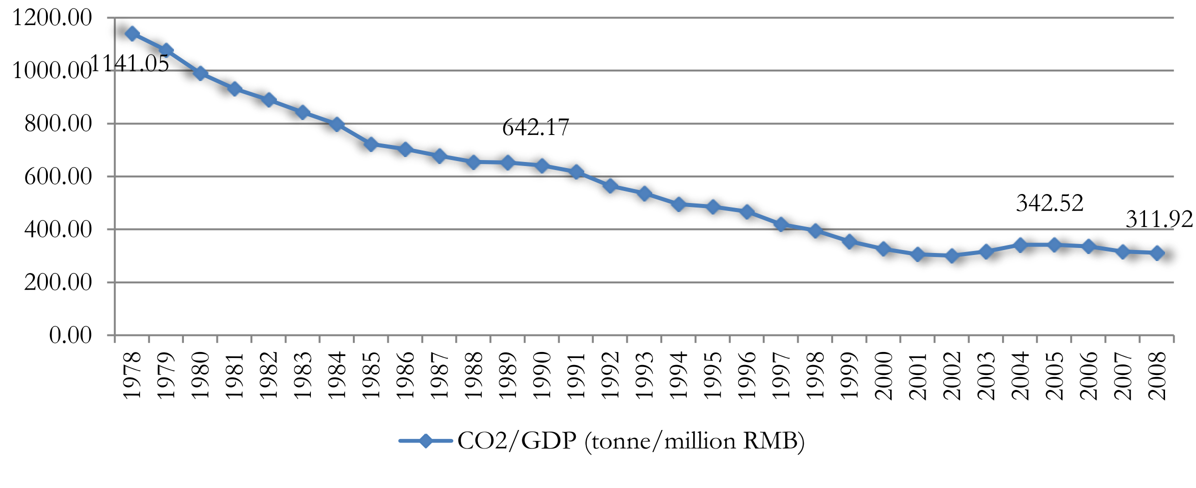

Figure 3-1 China's CO_2 intensity of GDP, 1978-2008
Source: National Bureau of Statistics of China (2010); and IEA (2010).

To project China's CO_2 emissions by 2020, it was assumed that the current economic growth will continue. Looking at the economic growth in the past three decades, the average growth rate was 9.92% per annum, the highest growth was 15.18% in 1984 and the lowest growth was 3.84% in 1990 (National Bureau of Statistics of China, 2011a). Especially since 2000, the growth in China's

GDP has remained over 8% per annum, and China overtook Japan as the world's second-largest economy in 2010 (Hamlin and Li, 2010). In its *Guidelines for the 12th Five-Year Social and Economic Development Programme (2011-2015)*, the Chinese government puts more focus on the contents and effects of economic development, rather than a purely high growth rate, and the average growth rate is expected to reach 7% per annum in the period, milder than before (China Daily, 2011). Considering these figures, China's future GDP was projected with growth rates of 7% and 10% per annum in this study.

Assuming that the CO_2 intensity will decrease at a constant rate annually, China's CO_2 emissions in the period 2009-2020 are shown in Table 3-1.

Table 3-1 China's CO_2 emissions, 2009-2020

(unit: million tonnes)	40% Reduction in CO_2 intensity		45% Reduction in CO_2 intensity	
	GDP growth at 7%	GDP growth at 10%	GDP growth at 7%	GDP growth at 10%
2008	8135			
2009	8632	8632	8592	8592
2010	8966	9218	8879	9128
2011	9305	9834	9165	9686
2012	9647	10481	9447	10265
2013	9991	11159	9724	10862
2014	10336	11868	9994	11476
2015	10680	12608	10253	12104
2016	11022	13376	10500	12743
2017	11360	14173	10731	13388
2018	11691	14994	10943	14036
2019	12012	15839	11133	14679
2020	12322	16702	11295	15310
Changes in 2020 cf. 2009	43%	93%	31%	78%

Source: National Bureau of Statistics of China (2010); and IEA (2010).

As shown in Table 3-1, if the mitigation target (40% reduction in CO_2 intensity) is met, China's CO_2 emissions will increase from 8632 million tonnes in 2009 to 12322 million tonnes in 2020, representing an increase of 43% (7% growth in GDP per annum). If the economy grows at 10% per annum, the CO_2 emissions will reach 16702 million tonnes in 2020, representing an increase of 93%. If the more ambitious target (45% reduction in CO_2 intensity) is met, China's CO_2 emissions will increase to 11295 million tonnes and 15310 million tonnes, referring to annual GDP growth of 7% and 10%, respectively. The absolute amount of CO_2 emissions will continue to grow under each situation, since the decrease in emissions intensity of GDP cannot offset the increase in GDP.

3.2 CO_2 emissions in the business-as-usual scenarios

While China announced the mitigation target and emphasised that the target would be pursued without referring to any other countries or relating to any other conditions, it is nevertheless arguable that China's CO_2 emissions will continue to increase, even if the target is met (see Paper III). It is important to know the emissions that must be avoided in order to achieve the mitigation targets compared with the business-as-usual situations without any mitigation compliance.

In general, three BAU scenarios in the period 2009-2020 were developed, based on the long-term relationship between CO_2 emissions and other macroeconomic variables:

- BAU1: CO_2 intensity of GDP remains constant after 2008.
- BAU2: CO_2 emissions grow following the historical relationship between CO_2 emissions, population and GDP, while energy consumption and international trade were not considered.
- BAU3: CO_2 emissions grow following the relationship obtained from the analysis on the EKC hypothesis in Section 2.2.2.

To reduce the complexity, changes in exchange rates, inflation/deflation and the interrelationship between each variable were not considered in the BAU scenarios.

3.2.1 The BAU1 scenario

Assuming that China will continue to develop its economy and that the CO_2 intensity of GDP will remain constant, China's future CO_2 emissions were estimated referring to annual GDP growth of 7% and 10%, respectively. The results are shown in Table 3-2.

Table 3-2 China's CO_2 emissions in BAU1, 2009-2020

	CO_2 emissions (million tonnes of CO_2)	
	GDP growth at 7%	GDP growth at 10%
2009	8885	8885
2010	9507	9773
2011	10172	10751
2012	10884	11826
2013	11646	13008
2014	12462	14309
2015	13334	15740
2016	14267	17314
2017	15266	19046
2018	16335	20950
2019	17478	23045
2020	18701	25350
Changes in 2020 cf. 2009	110%	185%

Source: National Bureau of Statistics of China (2010); and IEA (2010).

3.2.2 The BAU2 scenario

The historical relationship between CO_2 per capita and GDP per capita was determined, and then the BAU2 scenario was established according to this relationship. The estimates of China's population in the period 2011-2020 were taken from *China's Low Carbon Development Pathways by 2050-Scenario Analysis of Energy Demand and Carbon Emissions* (National Development and Reform Commission, 2009).

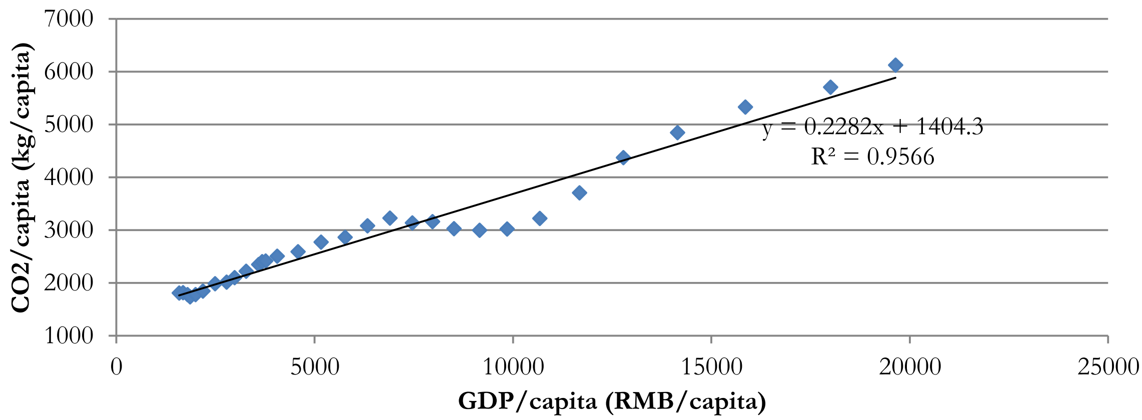

Figure 3-2 Relationship between GDP/capita and CO_2/capita, 1978-2008
Source: National Bureau of Statistics of China (2010); and IEA (2010).

China's CO_2 per capita and GDP per capita in the period 1978-2008 are shown in Figure 3-2. The relationship between CO_2 emissions per capita and GDP capita can be modelled by a linear regression, which was thus applied to the BAU2 scenario in this study. Following the linear relationship, China's CO_2 emissions in 2009-2020 are shown in Table 3-3.

Table 3-3 China's CO_2 emissions in BAU2, 2009-2020

	CO_2 emissions (million tonnes of CO_2)	
	GDP growth at 7%	GDP growth at 10%
2009	8375	8375
2010	8842	9037
2011	9342	9766
2012	9876	10565
2013	10447	11444
2014	11057	12409
2015	11708	13469
2016	12405	14634
2017	13149	15914
2018	13944	17321
2019	14795	18868
2020	15704	20568
Changes in 2020 cf. 2009	88%	146%

Source: National Bureau of Statistics of China (2010); IEA (2010); and National Development and Reform Commission (2009).

3.2.3 The BAU3 scenario

The BAU3 scenario was established on the basis of Equation 2-3, according to which China's CO_2 emissions are dependent on the settings of GDP, population, primary energy consumption and international trade. Primary energy consumption was assumed to continue to grow by 2020, specifically at a constant rate of 5.78% per annum, which is the average growth rate in the period 1980-2008. In contrast, other studies examining improvements in energy intensity regarding GDP often assume a slightly slower increase in primary energy consumption, e.g. the IEA suggested that China's primary energy demand would increase by 3.58% in the period 2009-2020 if new policies and technology were to be implemented (IEA, 2011). China's National Development and Reform Commission estimated that the primary energy demand would increase by 4.41% per annum in the period 2010-2020 in low carbon development situations (National Development and Reform Commission, 2009). It should be noted that the same amount of primary energy consumption, with an assumed increase of 5.78% per annum, was applied to our two scenarios with economic growth at 7% and 10% per annum, respectively. Consequently, energy efficiency, represented by GDP per unit of primary energy consumption, will improve faster in the scenario with economic growth of 10% than in that with growth of 7%.

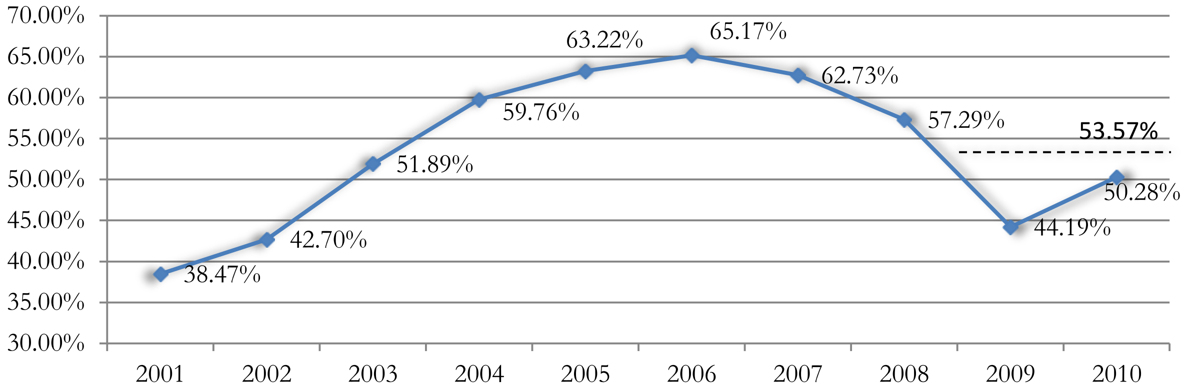

Figure 3-3 Trade openness ratio in China, 2001-2010
Source: National Bureau of Statistics of China (2010).

In addition, China's imports and exports have been growing dramatically since 1980 and the average trade openness ratio reached a level of 53.57% in the past decade. However, affected by the world economy, the trade openness ratio decreased to 44.19% in 2009 and returned to 50.28% in 2010, still below the average level (Figure 3-3). Considering these numbers, the trade openness ratio was assumed to remain at 53.57% in the period 2011-2020 in this study.

Based on the above assumptions, CO_2 emissions in the period 2009-2020 in BAU3 are shown in Table 3-4. Since growth in GDP has become a declining force for CO_2 emissions after the stationary point in 1982, the magnitude of CO_2 emissions will be smaller when GDP grows faster in BAU3.

Table 3-4 China's CO_2 emissions in BAU3, 2009-2020

	CO_2 emissions (million tonnes)	
	GDP growth at 7%	GDP growth at 10%
2009	7062	7062
2010	7313	7267
2011	7641	7542
2012	8071	7909
2013	8521	8289
2014	8994	8680
2015	9490	9084
2016	10010	9499
2017	10555	9927

2018	11126	10366
2019	11724	10817
2020	12345	11276
Changes in 2020 cf. 2009	75%	60%

Source: National Bureau of Statistics of China (2010); IEA (2010); and National Development and Reform Commission (2009).

In general, China's CO_2 emissions will continue to grow at a relatively high speed in the next decade in all three BAU scenarios, e.g. the emissions in 2020 will be 60-185% more than the level in 2009 in various scenarios. The relationship between the BAU scenarios in terms of CO_2 emissions is $\mathrm{BAU1} > BAU2 > BAU3$. Considering the BAU scenarios as regards GDP growth, it can be seen that CO_2 emissions will increase faster when GDP grows at 10% per annum than 7% in both the BAU1 and BAU2 scenarios, where GDP is a significant increasing factor for CO_2 emissions. In contrast, less CO_2 emissions will be produced when GDP grows at 10% rather than at 7% in BAU3, since GDP has become a declining factor for CO_2 emissions after 1982 according to the EKC hypothesis.

3.3 Emissions reductions according to the mitigation target

To have a clear sense of the effects of the mitigation target, the emissions according to the target were compared with the projections in the BAU scenarios. The results are shown in Table 3-5.

Table 3-5 Emissions reductions in comparison with the mitigation target

Unit: million tonnes of CO_2		(7% growth in GDP)		(10% growth in GDP)	
		CO_2 in 2020	Total (2010-2020)	CO_2 in 2020	Total (2010-2020)
	BAU1	18701	150052	25350	181112
	BAU2	15704	131270	20568	153993
	BAU3	12345	105792	11276	100656
Target (40%)	Absolute amount	12322	117332	16702	140252
	Change (cf. BAU1)	-6380	-32720	-8648	-40860
	Change (cf. BAU2)	-3382	-13938	-3866	-13741
	Change (cf. BAU3)	-24	11540	5426	39596
Target (45%)	Absolute amount	11295	112066	15310	133676
	Change (cf. BAU1)	-7407	-37986	-10040	-47436
	Change (cf. BAU2)	-4409	-19204	-5258	-20317
	Change (cf. BAU3)	-1051	6274	4034	33020

Source: National Bureau of Statistics of China (2010); IEA (2010); and National Development and Reform Commission (2009).

In the BAU1 scenario, where the CO_2 intensity remains at the 2008 level, China has to avoid a great amount of emissions in order to meet the mitigation target. The magnitude of CO_2 emissions that has to be avoided corresponds to a total of 32720 and 40860 million tonnes of cumulative emissions in the period 2010-2020 in order to reach a 40% reduction in CO_2 intensity, given an annual growth in GDP of 7% and 10%, respectively. To achieve a more ambitious target of a 45% reduction in CO_2 intensity, more efforts will be needed, namely 37986 and 47436 million tonnes of cumulative emissions will have to be avoided when GDP grows at 7% and 10%

per annum, respectively. Hence, the emissions in 2020 have to be significantly less than the BAU level if the mitigation target is to be met, i.e. 6380-10040 million tonnes of CO_2 will have to be avoided depending on different mitigation targets and economic situations (Table 3-5).

In the comparison between the target and the BAU2 scenario, similar results to those above are obtained. Fewer reductions will be needed to achieve the mitigation target, since the BAU2 scenario represents milder projections in terms of CO_2 emissions than BAU1. In order to decrease its CO_2 intensity by 40% by 2020, China has to reduce its cumulative emissions by 13938 and 13741 million tonnes of CO_2 in the period 2010-2020, with an annual growth in GDP of 7% and 10% respectively. A reduction of 19204 and 20317 million tonnes CO_2 emissions is needed to achieve a decrease in CO_2 intensity of 45%, given an annual growth in GDP of 7% and 10%. The emissions in 2020 will thus need to decrease by 3382-5258 million tonnes compared with the BAU2 situation (Table 3-5).

The results obtained from the comparison between the intensity targets and the BAU3 scenario are different from the above results. The magnitude of CO_2 emissions in the BAU3 scenario will be smaller than the level according to the intensity targets in 2020. Furthermore, the increase in emissions in the BAU3 scenarios will be greater as GDP grows faster, as a result of the EKC hypothesis and the attainment of the stationary point in 1982 (for more details, see Section 2.2). Concretely, if a 45% decrease in CO_2 intensity could be achieved by 2020, cumulative CO_2 emissions would increase by 6274 and 33020 million tonnes in the period 2010-2020 compared with the BAU3 scenario, given an annual growth in GDP of 7% and 10%, respectively. If a 40% decrease in CO_2 intensity could be achieved by 2020, the increase in cumulative emissions would increase by 11540 and 39596 million tonnes, with respect to an annual growth in GDP of 7% and 10%. In addition, if GDP grows at 10% per annum, the CO_2 emissions will increase by 5426 and 4034 million tonnes in 2020 compared with the BAU3 scenario, given a decrease in CO_2 intensity of 40% and 45%, respectively (Table 3-5).

To summarise, the amount of emissions that should be avoided by achieving the mitigation target in terms of CO_2 intensity depends heavily on the BAU scenario, i.e. how CO_2 emissions increased in the past and whether the increase will continue in the coming decade in the absence of the mitigation target. Significant differences in terms of CO_2 emissions and intensity were found between the three BAU scenarios developed in this study. Compared with BAU1, where CO_2 intensity remains unchanged, a great amount of reductions are necessary, given a decrease in CO_2 intensity of 40%-45%. In the comparison with BAU2, where the trend of CO_2 emissions was simulated by a linear model, the mitigation target still demands a significant amount of reductions, although lower than the amount in the BAU1 scenario. However, when a quadratic relationship, i.e. the EKC hypothesis, was applied to BAU3, the magnitude of CO_2 emissions according to the mitigation targets was actually larger than the level in the BAU3 scenario, even with the target of a 45% decrease in CO_2 intensity by 2020. It must be noted that none of the three BAU scenarios is more accurate than the others in terms of simulating the trend of CO_2 emissions. BAU3 in particular represents a conservative estimate of China's CO_2 emissions by 2020 among the three BAU scenarios (emissions in the past three decades were underestimated in BAU3 compared with the actual level, see Table 3-4).

In addition, while an argument on the mitigation target can be that CO_2 intensity will nevertheless decrease as public awareness improves and technology develops, the question is then whether the decrease in CO_2 intensity can be maintained at the same speed as before, especially in the absence of revolutionary breakthroughs in energy technology or costs for renewable energies. The likely empirical answer is 'probably not', since the decrease in China's CO_2 intensity has already been slowing down since 2000 (Figure 3-1). However, there is still hope for China to meet the target when comparing the emissions intensity in China with the levels in industrialised countries, e.g. the CO_2 intensity was 1555.10 tonnes per million USD in China in 2008 in contrast with 381.97 and 100.89 tonnes per million USD in the USA and Sweden, respectively (The World Bank, 2011). Therefore, achieving a 40%-45% reduction in CO_2 intensity in a decade is a challenging but hopeful target.

4 Policy instruments for climate change mitigation in China

In theory, the large-scale environmental problem of climate change is an unintended and uncompensated externality of a person's or a firm's activities and thus policy instruments are developed to help to solve the problem, so-called internalisation of externalities (Endres, 2010; Sterner, 2003). Due to its scale-up challenges, climate change mitigation is far more complicated than addressing small-scale environmental problems and requires individual contributions by local stakeholders to international cooperation between stakeholders at different levels (Sun, 2011).

Therefore, categories of policy instruments have been developed and adopted in practice since the 1990s in order to facilitate GHG reductions in one way or another. From an environmental economic perspective, policy instruments are often divided into economic instruments, or market-based instruments, such as subsidies, grants, taxes, fees and tradable permits, and administrative instruments, or so-called 'command and control' approaches, e.g. standards, bans, non-tradable permits or quotas, regulations, licences and liability rules (Jaffe and Stavins, 1995; The World Bank, 1997). In practice, economic and administrative instruments are often jointly implemented, namely markets involve regulations on prices and quantities and administrative instruments are often backed by economic sanctions (Sterner, 2003). As regards levels of administration, policy instruments include local instruments (municipal level and below), national instruments and international instruments, e.g. international emissions trading mechanisms, technology transfer programmes and other bilateral and multilateral agreements (Robert, 2003; Sterner, 2003).

This chapter discusses the policy instruments for climate change mitigation in China. In particular, domestic policy instruments, participation in international cooperation and other candidate policy instruments are described and analysed.

4.1 Domestic policy instruments

As the attention to climate change has greatly increased, the number of policy instruments and their stringency have accordingly increased rapidly in China since 2000 (National Bureau of Statistics of China, 2010). At an early stage, China's climate policies mainly focused on energy conservation and adjustments in energy structure in response to the challenges regarding energy, while CO_2 reduction had not yet become the main focus of national policies. Straightforward and rigid policies in terms of reducing CO_2 emissions have been launched since climate change mitigation was included in the national agenda, i.e. the *11^{th} Five-Year Social and Economic Development Programme (2006-2010)* (see Paper I). In the following sections, available domestic policy instruments, including administration instruments, regulation instruments and economic instruments, are specifically described and analysed.

4.1.1 Administration instruments

In this study, the term administration instruments specifically refers to administrative commands and permits launched and employed by the government from top to bottom in the administrative system, which are a special measure for the Chinese government to address environmental problems. Administration instruments are considered a useful measure to achieve an environmental target in China within a certain period (Dai and Bai, 2009). In order to analyse these administration instruments, it is necessary to be familiar with the administrative system of the Central People's Government of the People's Republic of China (CPGPRC), which is shown in Figure 4-1. Hierarchy is the most significant characteristic of China's administrative system, which includes national, provincial, municipality, county and town level from a top-down perspective. Note that Chinese municipalities include not only urban areas but also rural regions, which are called districts and counties in China's administrative system, respectively.

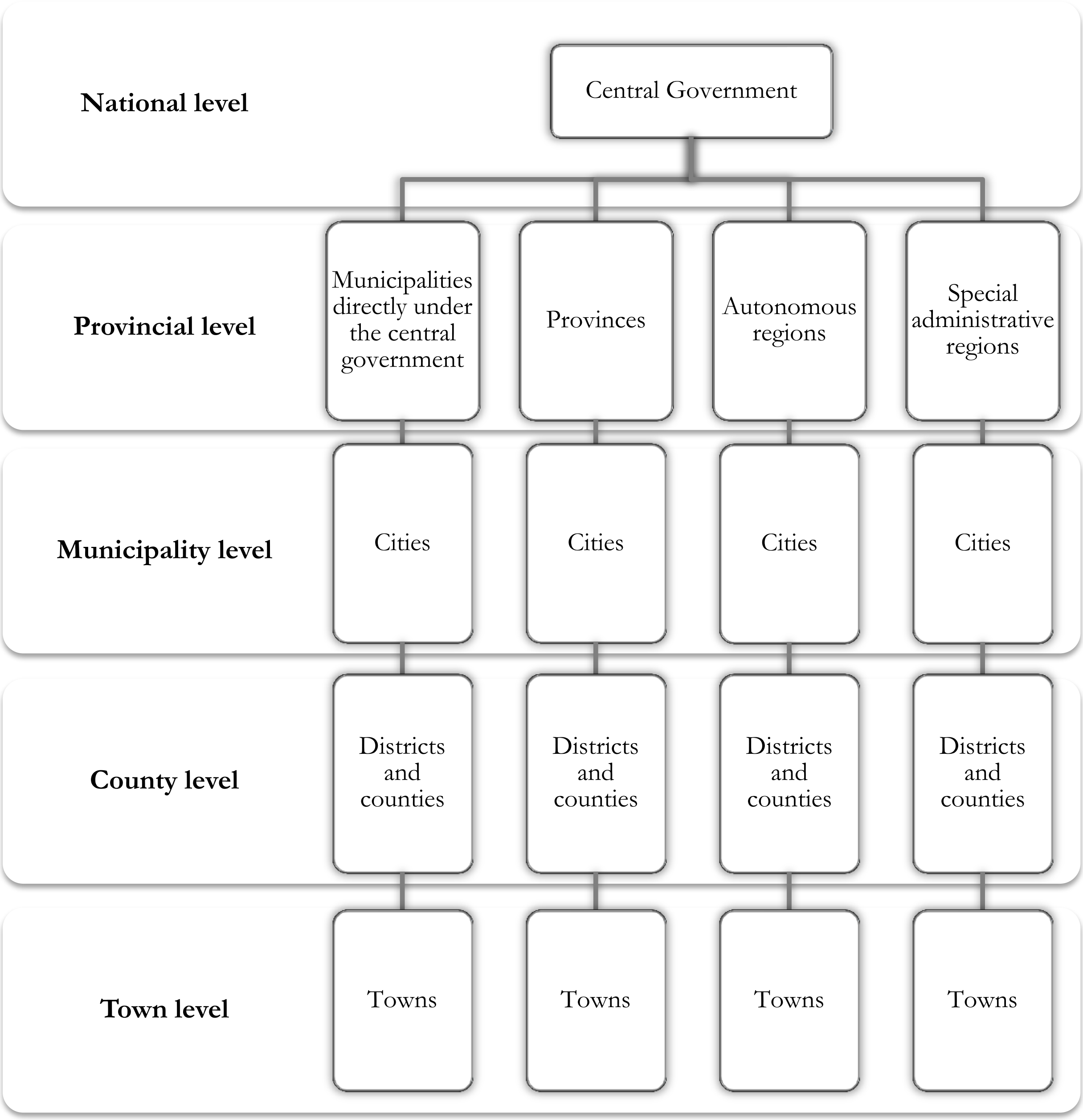

Figure 4-1 Administrative system of the Chinese government
Source: Adapted from CPGPRC (2005).

The implementation and evaluation of administration instruments are mainly based on geographical areas, which are under the governance of governments at different administrative levels. In general, administration instruments are often developed by the central government and then implemented by its underlying level of government, i.e. the provincial level, which in turn continues to assign the commands and permits to its underlying level of governments and level-by-level down to the bottom. Note that no government on any level may be skipped over and provincial and local governments may also develop and implement other legitimate instruments at their disposal, including other regulations and economic instruments (Dai and Bai, 2009).

With respect to climate change, the administration instruments adopted in China in recent years mainly consist of setting national targets, assigning targets to the provincial governments and establishing a penalties system to ensure compliance (see Paper I).

- Setting national targets

Taking the previous national target of decreasing energy intensity as an example, the central government decided to decrease end-use energy consumption per unit GDP by 20% by 2010 compared with the 2005 level (Ministry of Environmental Protection of the People's Republic of China, 2008). Various forms of end-use energy were included in this target, such as coal, crude oil, national gas, various forms of oil-and gas-derived products, and electricity.

- Assigning targets to provincial governments

When the national goal for 2010 had been defined, the central government broke down the overall target reduction in energy intensity and assigned specific targets to every government at the provincial level, excluding Hong Kong, Macao and Taiwan. Most provincial targets were set on the same basis as the national level, while the details of provincial energy supply and consumption were taken into consideration when the targets were assigned. For instance, the target assigned to Shandong province was to decrease energy intensity by 22%, since it was the largest energy consumer of all Chinese provinces (National Bureau of Statistics of China, 2010). Provinces, municipalities directly under the central government and autonomous regions were hence allowed to reach their assigned targets by all legitimate means at their disposal. The provincial government of Shandong further divided the target of a 22% decrease in energy intensity between the 17 cities in the province. The 17 cities thus had to try to meet the targets with all legitimate means at and below the city level.

- Establishing a penalties system

The administration instruments also comprise a penalties system, i.e. the Energy-Saving and Emissions Reduction Programme was launched in 2007 to guarantee achievement of the targets (CPGPRC, 2007). If a provincial target could not be met by 2010, the provincial government would be administratively 'penalised', namely the failure would carry significant weight in evaluations of the provincial government's work and the careers of relevant officials would be affected. In addition, the provincial government would have to prepare a compensatory programme within a month, specifically describing how the assigned target could be fulfilled in a given period, and then implement this programme.

In general, the characteristics of Chinese administration instruments include: (1) Mandatory: every government has to try to meet the target assigned by its upper level government and will be punished if it fails to do so; (2) top-down: this process only goes from the top administrative level to the bottom, rather than bottom-up; (3) mutual independence: administration instruments are implemented and evaluated on the basis of geographical areas and cannot be transferred between areas at the same administrative level; and (4) unbeneficial: there are no direct economic benefits or penalties relating to implementation of the administration instruments, while governments can develop other economic instruments within their disposal to encourage a decrease in energy intensity.

4.1.2 Regulation instruments

Regulation instruments mainly include various laws and regulations on performance of activities and technology (Sterner, 2003). In the past three decades, China has launched a number of environmental laws, in which those relating to climate change are shown in Table 4-1.

Table 4-1 China's laws relating to climate change

year of issued	Last revision	Law
1979	1989	Environment Protection Law of the People's Republic of China (PRC)
1987	2000	Law of PRC on the Prevention and Control of Atmospheric Pollution
1995	--	Electric Power Law of PRC
1996	--	Law of PRC on the Coal Industry
1997	2007	Energy Conservation Law of PRC
2002	--	Law of PRC on Promoting Clean Production
2002	--	Law of PRC on Environment Impact Assessment

Source: Project Management Office of National Communication Project (2007); and Dai and Bai (2009).

The Energy Conservation Law, issued on 1 November 1997, is one of the key items of legislation regarding regulations on energy saving and climate change mitigation in China (Dai and Bai, 2009). It provides a legal basis for activities on energy conservation, clearly defines the importance of energy conservation in China's social economic strategy and designates governments at various administrative levels as being responsible for related activities (Project Management Office of National Communication Project, 2007). The law was revised in 2007 in order to address the challenges relating to energy and climate change in a more effective way, e.g. the following changes were added:

- The application areas of the law were enlarged and sectors such as building, transportation and public service were included.
- An evaluation system, including standards and criteria, was established for examination of various facilities, assets and activities in terms of energy conservation.
- The roles of various government institutions and other parties in management and supervision of activities relating to energy conservation were clarified.
- Various forms of economic instruments were elaborated in order to encourage energy conservation.
- Illegal activities and related penalties regarding energy saving were defined.

Apart from laws, regulations on technology standards and restrictions are one of the most popular policy instruments in terms of environmental protection due to their characteristics of being easy to implement and fast acting, hence their wide adoption in China (Sterner, 2003). The regulations on technology standards and restrictions represent the most effective type of policy instruments with respect to decrease in energy intensity (Wen, 2009). A range of examples of such regulations can be seen in Table 4-2.

Table 4-2 Regulations on technology regarding climate change in China

Year	Regulation
1989	Decision on Key Issues on Industrial Policies at Present
1990	Decision on Further Improvement of Environment Protection Work
1994	Outline of China's Industrial Policies for the 1990's
1999	Disseminating Suggestions on Suspending Operation of small Thermo-Power Generating Sets
	Disseminating Suggestions on Winding-up and Reorganizing Small-scale Glass and Cement Plants
2000	Disseminating Notice concerning Suggestions on Reorganizing Small-scale Steel Mills
2006	Outline of China's Energy Saving Technology Policies
2007	Notice on Accelerating Shut-down of Small Thermal Power Units
2008	Standards of Energy Consumption for Energy-intensive Products
	Standards for Vehicle Fuel
	Standards of Energy Efficiency for End-use Energy Consumption Products
	Basic Standards for Energy Saving

Source: Project Management Office of National Communication Project (2007); and Dai and Bai (2009).

In September 2006, the Chinese government launched its *Outline of China's Energy Saving Technology Policies*, focusing on the promotion of Chinese energy-saving technology in the long-term (CPGPRC, 2006). In 2007, energy consumption per unit output for steel production was reduced by 6.4% compared with the 2005 level, for aluminium by 1.3%, for cement by 5.4% and for ethylene by 8.3% (Wen, 2009). Moreover, the government published its *Notice on Accelerating Shut-down of Small Thermal Power Units* in 2007, where strict baselines for thermal power plants regarding energy efficiency were developed (Dai and Bai, 2009). As a result, a large number of small power plants have been shut down and replaced by large thermal power plants with high efficiency. Compared with small power plants with the same capacity, these large thermal plants have been able to save up to 32.6 million tonnes of standard coal equivalent per annum since 2008 (National Development and Reform Commission, 2008).

4.1.3 Economic instruments

Compared with other policy instruments, economic instruments are market-based and considered more flexible and financially efficient, since they often offer a greater level of freedom to various parties (Sterner, 2003). The Chinese government has also applied a number of economic instruments, of which the major types include categories of tax, a progressive electricity tariff system and funding for mitigation actions. However, the widely discussed carbon taxes and domestic carbon market have not yet been established in China (for further discussion, see Section 4.3).

Since 2001, the Chinese government has used differential tax rates to encourage the development of renewable fuels and to restrict the use of fossil fuels. While the common value added tax (VAT) on coal power plants is kept at 17%, the VAT on wind power plants is 8.5%, that on production of ethanol energy is 13%, and energy production from biomass is exempted from VAT. Since 2007, the VAT on methane production and sales has started to be paid back to the energy-saving enterprises (see Paper I). In the meantime, other types of taxes, e.g. resource taxes, consumption taxes and export duties, have been applied to categories of energy resource and energy-intensive products in order to slow down the exploitation of fossil fuels. In 2009, the consumption tax on petrol increased from 0.2 to 1.0 RMB per litre and that on diesel increased from 0.1 to 0.8 RMB per litre. In the same year, the resource tax on coal was raised from 1% to 3% (Ministry of Finance of the People's Republic of China and Ministry of Environmental Protection of the People's Republic of China, 2008). In addition, the Chinese government subsidises electricity generated from renewables in order to make these competitive to fossil fuels, since power plants based on renewable energy usually entails larger investment costs than conventional fossil fuel-based power plants (see Paper I).

A progressive electricity tariff is an important instrument in adjusting the energy structure on the consumption side. Namely, consumers have to pay higher prices for their consumption of electricity over a certain level, which is pre-defined by the government. In 2004, progressive electricity tariffs initially applied to six energy-intensive industrial sectors, namely production of electrolytic aluminium, ferroalloy, calcium carbide, caustic soda, cement and steel. Since 2005, the system of progressive electricity tariffs has been expanded to cover all industrial sectors. In order to control electricity consumption more effectively, the rights to adjust electricity tariffs and to obtain the revenue from those tariffs were granted to provincial governments in 2007.

In 2007, the Chinese government allocated 1.33 billion RMB as a special fund for reducing CO_2 emissions and other pollutants. These funds can be used to: (1) build monitoring stations to record emissions of CO_2 and other pollutants; (2) provide funds for mitigation programmes; (3) expand the working capacity and facilities of environmental departments; and (4) reward provinces, cities and industries that have effectively mitigated emissions. Provinces can also use the funds in accordance with *Reduction of Major Pollutants, the Central Financial Management of Special Funds Interim Measures* (Ministry of Finance of the People's Republic of China and Ministry of Environmental Protection of the People's Republic of China, 2007).

4.2 Participation in international cooperation - CDM projects

In order to achieve emissions limitations and reductions worldwide, individual contributions by every stakeholder but also cooperation between these stakeholders are necessary (Sun, 2011). The greatest effort so far is undoubtedly the Kyoto Protocol to the UNFCCC, which defines the only legal binding structure existing in the world at present (Grubb, 2010). According to the 'common but differentiated responsibilities' under the UNFCCC, the Annex B countries must undertake quantified emissions limitation and reduction responsibilities, while developing countries are exempted from the mitigation liability in the first commitment period of the Kyoto Protocol before the end of 2012. To help the Annex B countries meet their mitigation targets, the Kyoto Protocol introduced three market-based mechanisms, namely Joint Implementation (JI), Emissions Trading Scheme (ETS) and CDM. Of these, CDM is the only one involving not only industrialised countries but also the developing world (Wu and Cheng, 2006). CDM is defined with dual aims, i.e. to help industrialised countries to achieve compliance with their emissions limitation and reduction commitments in a cost-effective way, while simultaneously assisting developing countries in sustainable development (see Paper II and Paper V).

China also participates in other international frameworks on climate change mitigation, e.g. APP, which attempts to achieve progress on climate change based on technology transfer outside the Kyoto Protocol process, but does not make any concrete commitment to reduction (Heggelund and Buan, 2009; Kellow, 2010; Lawrence, 2007; McGee and Taplin, 2009). However, there has not been any framework comparable to the Kyoto Protocol in terms of either amount of GHG reductions or political influence worldwide. So far, CDM has been the most important way for China to participate in international cooperation on climate change mitigation. This study thus focused on CDM in terms of China's participation in international cooperation on climate change.

4.2.1 Review of China's CDM project activities

Figure 4-2 shows China's CDM projects in the period 2005-2011 and the data on number of projects and magnitude of CERs represent newly registered projects in each year. However, a CDM project can continuously generate CERs through its crediting period, normally 7 years. In the early stage before 2005, China had no CDM projects registered in the UNFCCC's database. The Chinese government doubted whether CDM would become a way by which the Annex B countries could escape their mitigation responsibilities and, more importantly, whether payment for CERs could really be made (Heggelund, 2007; Schroeder, 2009). After several initial projects, the government changed its attitude toward CDM and started to encourage development of CDM project activities in China. A sign marking this change was the enactment of the *Measures for Operation and Management of Clean Development Mechanism Projects*, which replaced the old interim measures and more clearly defined the regulations on CDM (Bei et al., 2011; National Coordination Committee on Climate Change, 2005; Pezzey, 2003). However, it has been noted that the development of CDM projects is mainly based on project owners' initiative, although the Chinese government is greatly encouraging CDM project activities, especially those relating to renewable energy (Sun, 2011).

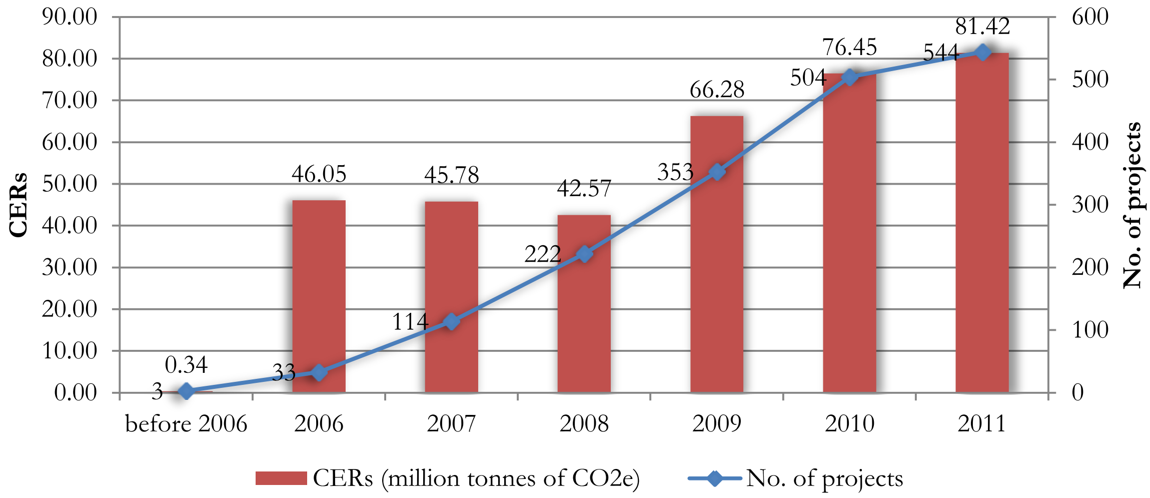

Figure 4-2 China's CDM projects in the period 2005-2011
Source: UNFCCC (2012a).
Note: Some projects registered in late 2011 may be missing from the database, because it was accessed in January 2012.

Rapid growth in the total amount of projects and related CERs started in 2006 and even the economic recession that developed in the second half of 2008 did not have any significant impacts on growth. By the end of 2011, a total of 1773 projects in China registered in the UNFCCC's database, accounting for 47% of all CDM projects and these projects would annually generate 358.89 million tonnes of CERs, accounting for over 60% of the total CER credits worldwide. In addition, it was announced at the Durban conference that as a mechanism under the Kyoto Protocol, the CDM will continue after 2012 and thus more project activities and related reduction credits will be delivered (UNFCCC, 2012b).

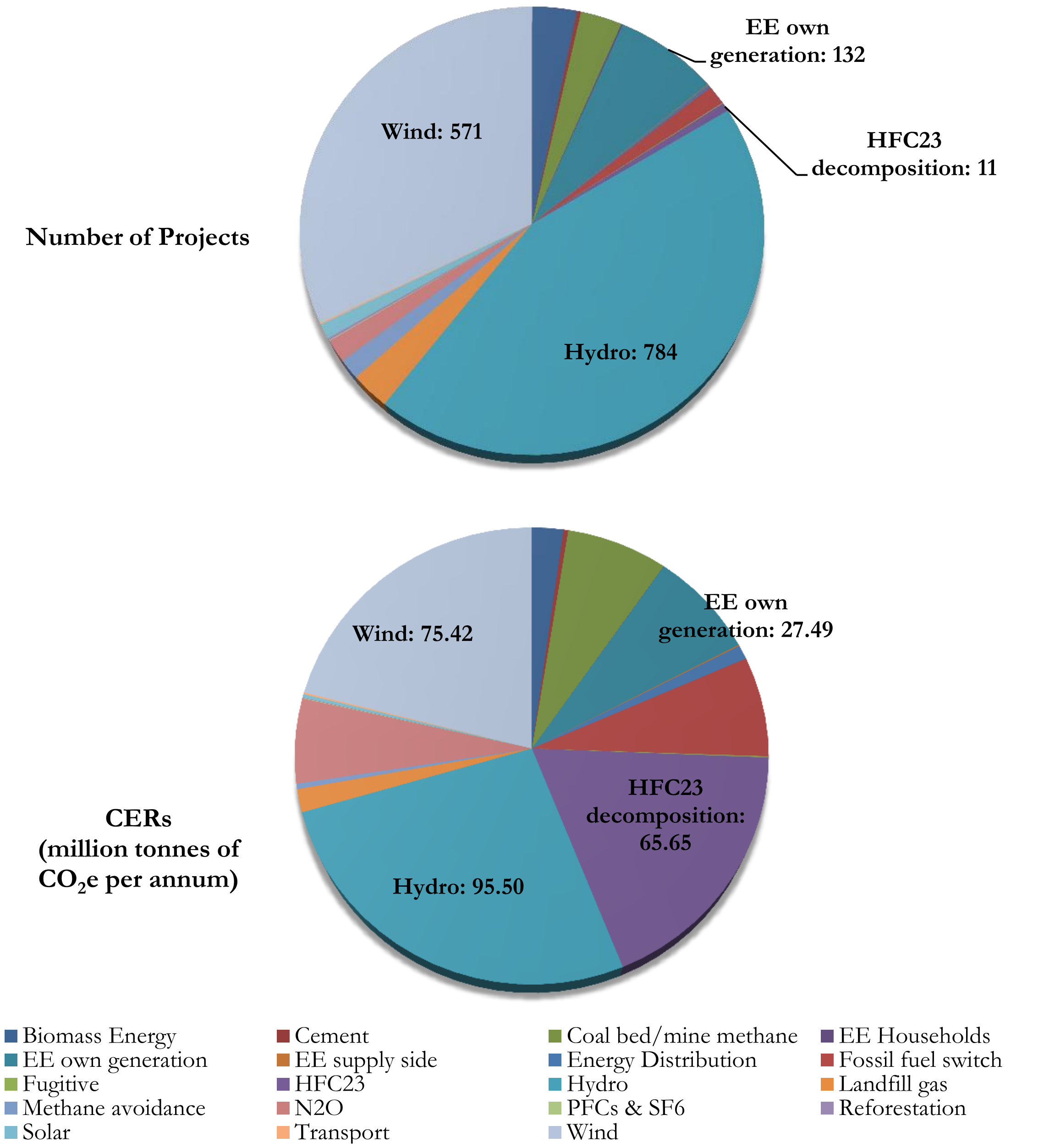

Figure 4-3 China's registered CDM projects by category by the end of 2011
Source: UNFCCC (2012a).

Looking into China's CDM projects by the end of 2011, there had been in total 19 categories of activities, within which hydropower, wind power and energy efficiency (EE) own-generation projects, where electricity is produced from waste gas or waste energy, are the three largest categories in terms of number of projects, together representing 83.88% of China's CDM projects (Figure 4-3). This number reflects China's energy policy in the past decade, which aims to promote renewable energy and to restrict fossil fuels (Section 4.1.3). In terms of amount of CERs, hydropower, wind power and HFC23 decomposition projects are the three largest categories, which can generate 95.50, 75.42 and 65.65 million tonnes of CERs per annum, respectively. EE own-generation, with 27.49 million CERs per annum, is the fourth largest category (Figure 4-3). It is interesting that there are only a total of 11 HFC23 decomposition projects registered in the database, but these 11 projects can generate 65.65 million tonnes of CERs per annum, indicating a large mitigation capacity on average. However, due to the limited amount of overall HFC23 production, no new project has been registered in this category since April 2009 (UNFCCC, 2012a).

4.2.2 China's CDM regarding its dual aims

As mentioned earlier, the CDM has dual aims, i.e. to help industrialised countries to achieve their reduction commitments in a cost-effective way, while simultaneously assisting developing countries in sustainable development. In practice, industrialised countries concentrate on whether CERs are cost-effective compared with other reduction credits on the international carbon market or reductions achieved in their domestic emissions, while the examination of CDM's impacts on local sustainability is mainly left to developing countries (Sutter, 2003).

There has not been much debate on CDM regarding its cost-effectiveness, since the costs for constructing low-carbon energy infrastructure in developing countries are generally cheaper than those for modifying or replacing existing facilities in industrialised countries (Wara, 2007). By comparing the average CER prices on the international market with marginal mitigation costs in industrialised countries, global average costs for maintaining the CO_2e level at 450 ppm and the market prices of reduction credits from other mechanisms, Sun (2011) shows that CDM represents a cost-effective option for industrialised countries to achieve their reduction commitments and China's CDM projects are important for maintaining CER prices at a low level due to their dominant share in the entire mechanism. As for the amount of CERs, Sun (2011) also shows that China's CDM projects were able to supply over 50% of the total reduction commitments of industrialised countries according to the Kyoto Protocol by the end of 2010 and this number will be much larger when CDM projects in all developing countries by the end of 2012 are considered. Therefore, it can be concluded that the aim in terms of helping industrialised countries to achieve their reduction commitments in a cost-effective way is being met. In the meantime, the CDM is also helping China limit the growth in CO_2 emissions, although the effect is small, i.e. about 3% of China's overall emissions, due to the dominance of fossil fuels. However, the CDM is important for stimulating renewable energy in China, e.g. about 11% of hydropower and 93% of wind power was generated by CDM projects in 2010 (Sun, 2011). In addition, whether the reductions credits, with double mitigation effects in developing and industrialised countries, are double counted depends on how China defines its mitigation targets. There is no problem of double counting until China starts to commit itself to reduction targets on the basis of an absolute term (Sun, 2011).

In contrast, the target in terms of assisting developing countries in their sustainable development is much more complicated to assess, because sustainable development refers to different contents in different places at different times and there has not been any method to date capable of assessing the comprehensive concept of sustainable development in a completely satisfactory way (see Paper II and Paper V). In practice, the UNFCCC has not developed any methodologies for safeguarding sustainable development and therefore different developing countries perform the examinations in different ways (Disch, 2010). In China, a CDM project must be in line with China's national strategies on sustainable development and comply with related policies. In order to get a letter of approval, a candidate project needs to show the future impacts on sustainable development during the project's construction and operation phase (National Development and Reform Commission et al., 2011). However, the Chinese government has not provided any guidelines on how the comprehensive concept of sustainable development should be assessed and, in most cases, only an environmental impact assessment is carried out to address sustainable development in an incomplete way. Some studies have attempted to evaluate CDM's impacts on sustainable development. Popular methods in such evaluations include quantitative methods, e.g. Cost Benefit Analysis (CBA) of co-impacts, or 'ancillary impacts', which refers to various economic, environmental and social impacts apart from GHG reductions, simultaneously caused by climate change mitigation activities (Aunan et al., 2006; Aunan et al., 2004; Cao et al., 2008; Disch, 2010; Haines et al., 2006; Vennemo et al., 2006); and qualitative (or semi-quantitative) methods, e.g. Multi Criteria Analysis (MCA) and meta-CDM (Heuberger et al., 2007; Kolshus et al., 2001; Olsen and Fenhann, 2008; Sutter and Parreño, 2007).

Paper II presents a CBA of co-impacts applied to the 128 CDM projects in the cooperation between China and Sweden by 31 July 2010. It was found that a great amount of co-benefits apart from CERs were simultaneously generated. These co-benefits included:

- A 76.13 million tonnes reduction in SO_2
- A 4.92 million tonnes reduction in particulate matter
- A 18.03 million tonnes reduction in NO_X
- 321 avoided deaths
- 462.87 million RMB avoided crop losses.

Since the co-benefits have so far not been seriously considered in policy design regarding climate change, Paper II discusses the policy implications of these co-benefits from three aspects, namely: (1) Should co-benefits be included in the current international negotiations regarding CDM? (2) Should co-benefits be used to ensure the contribution of CDM projects to sustainable development? and (3) What possible policy implications arise from different co-benefits?

It is suggested that co-benefits should not be involved in current international negotiations on climate change and should not be used to ensure project contributions to sustainable development. However, the synergies or optimised trade-offs between climate change mitigation and other environmental benefits, which are indicated by co-benefit analysis, are valuable for decision-making in developing countries, especially for local governments, which often have a limited budget on multiple environmental targets (for further discussion, see Paper II).

In Paper V, two CDM projects were studied in terms of their impacts on sustainable development in an experimental study, using the Analytic Hierarchy Process (AHP) method, which was developed by Saaty (1977) in the 1970s and uses pairwise comparisons to measure how much one element dominates over another with respect to a given impact (Saaty, 1980; Saaty, 1990; Saaty, 2005; Saaty, 2008). A detailed description of the AHP method can be found for example in Saaty (1980; 1990; 2008), Ramanathan (1999; 2001) and Berrittella et al. (2008). By arranging impacts in a hierarchic structure, the AHP method may be especially appropriate for comparing a limited number of projects with respect to dimensions of impacts on sustainable development, mixing both qualitative and quantitative information (Ramanathan, 1999; Ramanathan, 2001; Vaidya and Kumar, 2006).

Two experimental groups of post-graduate students performed the assessment and both found that the HFC23 decomposition project studied (reference no. 0304) was a greater contributor to sustainable development than the hydropower project (reference no. 2255), especially in terms of environmental impacts. In general, the AHP method features a system structure that is effective in breaking down a comprehensive problem into pairwise comparisons and demands intensive participation by stakeholders, which is important for local sustainable development. However, the AHP method is weak in that: (1) Break-down and weighting of criteria can be very subjective; (2) the final results depend heavily on the participants in the assessment; (3) only a limited number of alternatives can be considered; and (4) the final results are difficult to use elsewhere. As regards policy implications, wide application of the AHP method is restricted by its weaknesses, especially the last two points. However, a bottom-up participatory process through engaging local stakeholders in CDM design and approval could be more useful for safeguarding local sustainable development than any ex ante methods (for further discussion, see Paper V).

4.3 Other policy instruments

Although a 20% decrease in end-use energy intensity compared with the 2005 level had been achieved by 2010, such significant improvements in energy efficiency as in the past three decades are unlikely to be maintained (see Figure 3-1), unless more effective policy instruments can be implemented. Compared with other instruments, carbon tax and domestic emissions trading are two market-based instruments characterised by high economic efficiency and thus highly recommended by environmental economists (Lin and Li, 2011; Pizer, 2002; Sterner, 2003). As they have both been on China's policy agenda (Cao, 2010; China 5E.com, 2010), this section focuses on them especially with regard to their potential application in China, on the basis of a literature review.

4.3.1 Carbon tax

The taxation levied on categories of energy, especially fossil fuels and their related products, according to their carbon content in order to reduce energy consumption and CO_2 emissions is known as a carbon tax (Ekins and Baker, 2001; Lin and Jiang, 2009). The benefits of carbon taxes are usually summarised as 'double dividend' (Bovenberg, 1999; Goulder, 1995). A carbon tax directly increases the costs of energy-intensive industries and thus promotes energy saving, substitution of fossil fuels and investments on energy technology, which will thus result in changes in energy structure and a reduction in CO_2 emissions (Cao, 2010; Ekins and Baker, 2001; Smulders and Sen, 2003; Zhang and Baranzini, 2004). Furthermore, the carbon tax increases government's revenue, which can be recycled and further used, for example to subsidise energy saving and mitigation activities and to reinforce the mitigation effects (Garbaccio et al., 1999; Weitzman, 1974).

However, a carbon tax, like other policy instruments, inevitably has its own drawbacks, of which the primary concern is its impact on the economy. As the price of energy and related products becomes higher, the costs for businesses will grow, household consumption will decrease, the strength of energy-intensive and international trade sectors will be weakened and growth in the entire economy may slow down (Liang et al., 2007; Lin and Li, 2011; Lu et al., 2010). Since these negative impacts can be substantially heavy in developing countries, there has been a controversy on whether carbon taxes should be imposed in China at present, e.g. Cao (2010) suggests that a carbon tax is likely to be more effective than other instruments in terms of CO_2 reductions, while Lu (2009) argues that it is still too early to launch carbon taxes in China. In addition, the mitigation effects of a carbon tax depend on a wide range of factors, which include: (1) tax rates and tax bases; (2) transfer of taxes from producers to customers; and (3) recycling of tax revenues, e.g. tax exemption and reimbursement. Since a Pigovian tax (Pigou, 1920), i.e. the tax to internalise environmental externalities, is difficult to decide in practice, all the carbon taxes that have been in place to date are introduced to address defined targets of CO_2 reductions, rather than based on calculations of optimality (Ekins and Baker, 2001; Pizer, 2001). A carbon tax may have different effects on mitigation and different acceptability if it is levied on different tax bases, even with the same tax rate. When carbon taxes are charged, companies may transfer the increased costs to their customers by increasing the price of their products. If the demand elasticity of those products is high, i.e. if the customers are sensitive to changes in price, a carbon tax will have significant mitigation effects. Otherwise, the demand on those products will not be significantly reduced and the carbon tax will be transferred to the end-customer. As a result, the carbon tax will mainly increase fiscal revenue, rather than contributing to CO_2 reduction. In order to reinforce the effectiveness of a carbon tax and overcome its likely drawbacks, the revenues from that carbon tax can be recycled back to energy-intensive and international trade sectors by way of tax exemption or reimbursement. However, in practice the revenues are absorbed into the government budgets in most countries (Liang et al., 2007; Lin and Li, 2011; Lu et al., 2010). In addition, whether the recycling of tax revenues undermines the motivation of industries regarding climate change mitigation needs to be further determined.

In practice, carbon taxes have been imposed in Finland, the Netherlands, Sweden, Norway, Denmark, Switzerland, Ireland, Costa Rica, India, Quebec (a province of Canada) and Boulder (a city in the USA). It has been noted that the structure of those carbon taxes, i.e. tax rates and related recycling systems for tax revenue, differ across these countries and places, resulting in different effects on climate change mitigation. For example, carbon taxes, together with energy taxes and electricity certificates, make a great contribution to the Swedish energy sector in terms of limiting CO_2 emissions and promoting electricity production based on renewables (Ministry of Sustainable Development, 2005). In contrast, Bruvoll & Larsen (2004) suggested that carbon taxes contributed to CO_2 reductions by only 2% of annual emissions in Norway in the period 1990-1999, while in the meantime there had been an overall 14% decrease in Norway's annual CO_2 emissions. By employing the method of difference-in-difference, Lin & Li (2011) also reported that carbon taxes have scarcely had any impact on CO_2 emissions in Norway, while they exerted a significant impact in Finland.

As for the on-going discussion on carbon taxes in China, it is likely that carbon taxes will be first levied on companies according to their energy consumption in the period of the 12^{th} five-year (2011-2015) plan (China 5E.com, 2010). According to the special report on China's carbon taxes, the tax rate is proposed to be 10-20 RMB per tonne of CO_2 emissions at the beginning and will gradually increase to 40-50 RMB per tonne of CO_2 emissions by 2020. Revenues from carbon taxes may be distributed between the central government and local governments at a ratio of 7:3 in order to improve the enforceability of carbon taxes at the local level. In addition, an associated recycling system for tax revenue, including tax exemption and reimbursement, will be introduced in order to alleviate the pressure on the national economy. At present, many details regarding the carbon tax and the revenue recycling system still remain to be decided before its official launch.

In conclusion, carbon taxation is a useful instrument for reducing CO_2 emissons at lower costs than regulations, while its actual effects depend on a number of complicated conditions beyond its own scope. The main challenge in practice concerns how to balance a carbon tax and the associated recycling measures, which should alleviate the negative impacts on the economy without sacrificing mitigation effects.

4.3.2 Carbon emissions trading

Another market-based policy instrument is carbon emissons trading (CET), which aims to achieve emissions reductions at the least social cost by allowing emissions permits to be traded on the market (Ekins and Baker, 2001; Sterner, 2003). The theoretical foundation of CET derives from Coase's famous analysis on property rights (Coase, 1960) and its initial introduction is generally ascribed to Dales (1968), who was the first to explicitly proposed a 'market in pollution rights' as a policy instrument to protect water bodies in Ontario, Canada. Emissions permits can be decided according to existing standards or regulations, e.g. this approach was previously used in the Clean Air Act by the United States Environmental Protection Agency in 1974, but it has generally not been adopted since because of the rigidity and complexity associated with regulations (Bing et al., 2010; Sterner, 2003). In contrast, cap-and-trade schemes reduce those administrative burdens and transaction costs and have thus replaced the standard approach and become the major form of emissions trading mechanisms. A cap-and-trade scheme is based on absolute emissions levels, which define the emissions permits for participating parties. The emissions below the permitted level can be traded on the market and used to offset buyers' emissions. Emissions trading schemes are considered cost-effective because parties with high reduction costs will choose to buy emissions permits from parties with low reduction costs, rather than decreasing their own emissions.

Two frequently discussed methods for allocating emissions permits are 'grandfathering', i.e. participating parties can receive emissions rights free of charge based on their historical or current emissions, and 'auction-off', where all parties have to purchase their emissions rights in an auction system (Woerdman et al., 2008). In principle, an auction-off emissions trading scheme resembles a carbon tax system when the auction price is set at the level of the tax rate, given the assumption on efficient auction settings. Carbon taxes and auctioned tradable permits can both raise government revenue, which can be further recycled to achieve double dividends along with emissions reductions, and thus are preferable to grandfathering schemes from a economic efficiency perspective (Ekins and Baker, 2001). In contrast, the acceptance of grandfathering schemes in practice is clearly higher than that of auction-off systems, especially in energy-intensive and international trade sectors, since participating parties do not need to spend extra money on emissions permits. However, the debate is not over, e.g. Sorrell & Sijm (2003) argued that grandfathering systems violate the polluter-pays principle and thus are unfair in terms of environmental equity. Conventional sectors with high emissions levels will be protected under a grandfathering scheme, while the development of new industries will be hampered (Cao, 2010).

This argument was further discussed by Woerdman et al. (2008), who claimed that grandfathering is compatible with an efficiency interpretation of the polluter-pays principle, because pollution costs have been internalised, while the auction-off system not only ensures efficiency, but also equity relating to distribution of costs between various parties.

In the early 1990s, an emissions trading scheme for cutting down sulphur dioxide emissions was established through the Clean Air Act Amendments by the United States, and it is generally considered a successful example of a cap-and-trade scheme (Hepburn, 2007; Woerdman et al., 2008). In the USA, cap-and-trade schemes have also been applied to protecting regional water bodies and managing fish stocks in Alaska, and an in-depth analysis of these schemes can be found in Colby (2000). In Europe, several countries have operational trading schemes for reducing various ambient pollutants, such as the trading programme in the former Czech and Slovak Republic for reducing sulphur dioxide and the Netherlands for decreasing nitrogen oxides (Sterner, 2003). The most successful example in developing countries by far is the permit scheme applied to industrial particulate matter in the metropolitan region of Santiago, Chile (Sterner, 2003). In this scheme, any new participant has to purchase its credits from existing permits, while the total amount of permits has been reduced over time in order to achieve reductions.

In terms of GHG emissions reduction, the European Climate Change Programme (ECCP), comprising a comprehensive package of measures, was initiated in the early 1990s and it encouraged EU Member States to put in place their own domestic instruments built on the ECCP measures or to complement them (European Commission, 2010b). The current European Union Emissions Trading Scheme (EU ETS), which now operates in 30 European countries, namely the EU-27 Member States plus Iceland, Liechtenstein and Norway, to help them achieve their mitigation commitments in a cost-effective way, is currently the largest CET scheme worldwide (Christiansen and Wettestad, 2003; Sun, 2011). Launched in 2005, EU ETS now covers CO_2 emissions from some 11000 power stations and industrial factories and operates in 30 European countries (European Commission, 2010a). With the lack of post-2012 regulatory clarity, the dominance of the EU ETS allowances (EUAs) on the global carbon market became more pronounced than ever. The total value of the EUAs increased to 119.8 billion US dollars in 2010, accounting for 84.42% of the global carbon market (Christyakova et al., 2011).

The concept of emissions trading has also been speading across China. Three emissions permits exchange companies were founded in 2008, in Beijing, Tianjin and Shanghai, and they have established the platforms for environmental property rights trading regarding SO_2, Chemical Oxygen Demand (COD) and voluntary emissions reductions (VERs) (Christyakova et al., 2011). However, the platform for CET has so far not been established. While domestic emissions cap-and-trade schemes have been proposed to help reduce energy intensity and CO_2 emissions, it has been noted that the existing modes of CET in industrialised countries should not be directly applied to China (Guan and Hubacek, 2010; Li, 2012). Although the early pilot programmes of CET in Taiyuan, Guangdong and other places have failed, the Chinese government is going to establish a larger experimental CET programme than ever before in seven Chinese provinces and cities, namely Beijing, Tianjin, Shanghai, Chongqing, Guangdong, Hubei and Shenzhen (Li, 2012; Raufer and Li, 2009). The programme will be launched by the end of 2013 but many details have not been clearly specified to date, e.g. the emissions inventories of those provinces and cities, the decision on emissions caps, the pricing system on emissions permits and laws and regulations regarding the domestic carbon market (Bei et al., 2011; Wang, 2012). In addition, the impacts of the domestic CET programme on China's potential for CDM projects remain to be further investigated.

Lastly, there is a great deal of literature reporting comparisons between environmental taxes and emissions trading schemes and a review of such early studies can be found in Ekins & Baker (2001) and Stavins (2003). The main distinction between taxes and trading systems has been described as controlling CO_2 emissions via price-based or quantity-based measures (Weitzman, 1974). Price-based measures, i.e. taxes, fix the marginal reduction cost at the tax rate and thus generate a range of reductions, given the uncertainties in reduction costs. In contrast, quantity-based measures, i.e. emissions trading schemes, precisely define the level of reductions and leave uncertainties regarding reduction costs (Pizer, 2002). Researchers attempting to analyse which instrument is more efficient have found that the answer depends on a number of assumptions on damage costs, mitigation costs and their marginal changes. In principle, if the marginal benefit (or marginal damage costs) curve is flatter than the marginal cost curve, a price-based instrument may be more efficent than a quantity-based instrument, and vice versa (Cao, 2010; Pizer, 2002; Stavins, 2003). For the case of CO_2 emissions, the marginal benefits of reductions relate to the stock of CO_2 emissions, which can only be slightly influenced by mitigation activities, while the marginal costs of reductions correspond to the magnitude of redcutions and concrete approaches to achieve the reductions. Therefore, price-based instruments, e.g. carbaon taxes, are possibly more efficient for CO_2 reductions. However, the simplicity, transparency, acceptance and costs relating to the development, distribution and administration of a mitigation target are usually not considered, and these issues may switch the advantage from taxes to emissions trading schemes (Ekins and Baker, 2001; Pezzey, 2003). Most reduction targets and mitigation projects, programmes and mechanisms in practice have been based on quantity controls, while price-based measures have only been adopted in relatively few countries and at relatively low levels (Ekins and Baker, 2001). More importantly, climate change mitigation is different from addressing other environmental problems, where an ad hoc policy instrument can effectively cut down pollution and protect the environemnt (Sun et al., 2010). While it is important to understand the relative pros and cons of taxes and emissions trading schemes, at the same time it is necessary to address the ubiquitous challenge of climate change from different aspects and at different levels, for which categories of policy instruments may be simultaneously needed. Therefore, it is more interesting and valuable to focus on hybrid policies and to determine an optimised combination of carbon taxes and CET schemes for a given situation. Some previous studies have pointed out the advantages of hybrid policies over any instrument alone (Pezzey, 2003; Pizer, 2003; Roberts and Spence, 1976), while many details especially as regards design and application in practice still remain to be studied, e.g. how to combine carbon taxes and CET schemes in China in order to achieve a 40% reduction in carbon intensity by 2020 in the most cost-effective way.

5 Discussion

Given that the challenges of climate change continue to grow, every country has the unshirkable responsibility for limiting and/or reducing its emissions to a reasonable level. According to the principle of common but differentiated responsibilities, developing countries do not need to undertake compulsory reduction commitments in the present stage of the Kyoto Protocol. However, this is not to say that developing countries should let their emissions grow without doing anything. The rapid growth in CO_2 emissions, especially since 2000, has made China the largest emitter in the world, accounting for around 23% of the world's total emissions in 2010, and China's per capita emissions have also surpassed the world's average level (Chinanews.com, 2011; Sun, 2011). Therefore, as the largest developing country and the largest CO_2 emitter, the dynamics of China's emissions and China's attitudes toward mitigation are of great importance.

Using the most widely studied macroeconomic factors and time-series data for the period 1980-2008, the existence of an EKC relationship between CO_2 emissions per capita and GDP per capita was verified here. However, China's overall CO_2 emissions will continue to grow in coming decades and the turning point will appear in 2078, according to a crude projection whereby economic growth is assumed to be 10% per annum. Comparing this result with other published data, most previous studies agree on the existence of a long-term relationship between China's CO_2 emissions and GDP, but disagree on whether the relationship supports the EKC hypothesis. The differences arise from the impact factors and/or the data adopted in different models. It must be noted that the EKC hypothesis represents a statistical relationship between empirical changes in CO_2 emissions and GDP, rather than a fundamental theorem predicting a fact that will occur regardless. Many important conditions apart from growth in GDP are necessary for the EKC hypothesis, e.g. improvements in public awareness, technology and education, and they are not ensured by the growth in GDP. This means that: (1) the existence of an EKC relationship between China's CO_2 emissions and GDP indicates a theoretical possibility of a decrease in China's CO_2 emissions, especially when the turning point has already passed; (2) China's CO_2 emissions will not spontaneously decrease as GDP grows, unless every impact factor changes in the same way from now on as it did in the past three decades; (3) the accelerating growth in China's CO_2 emissions is likely to deviate from the past trend according to the EKC relationship, where growth in GDP is a declining factor for CO_2 emissions after 1982; and (4) a new relationship will be created as more data become available in future and whether this relationship is in line with the EKC hypothesis needs to be verified again.

To address the growth in CO_2 emissions without disrupting economic development, the Chinese government aims to reduce the CO_2 intensity of GDP by 40%-45% by 2020 compared with the 2005 level. Even if the target is achieved, China's CO_2 emissions could still increase to the range of 11295-16702 million tonnes in 2020, depending on an annual growth in GDP of 7-10%, which represents an increase of 31%-93% compared with the 2008 level. To evaluate the mitigation effects of the target, the emissions according to the target were compared here with three BAU scenarios, which were BAU1: CO_2 intensity of GDP remains unchanged; BAU2: CO_2 emissions grow following the historical relationship between CO_2, population and GDP; and BAU3: CO_2 emissions grow following the EKC relationship. Compared with BAU1 and BAU2, a great amount of emissions have to be reduced in order to achieve the mitigation target, namely 13741-47436 million tonnes of cumulative CO_2 emissions will have to be avoided in the period 2010-

2020, depending on an annual growth in GDP of 7-10%. In contrast, the BAU3 scenario represents a very conservative projection of China's future CO_2 emissions and more emissions than the BAU3 level will be generated even if a 45% reduction in CO_2 intensity is achieved, namely an increase of 6274-33020 million tonnes in cumulative CO_2 emissions in the period 2010-2020. Nevertheless, decreasing CO_2 intensity by 40%-45% by 2020 is still an hopeful target, especially when comparing the emissions intensity in China with the levels in industrialised countries. Although the target was not based on an absolute amount, it is the first straightforward commitment that China has made to limit the growth in CO_2 emissions, and represents an important step towards China undertaking much more significant mitigation responsibilities in the future.

Responding to both domestic and international pressure on energy consumption and CO_2 emissions, the Chinese government has adopted categories of policy instruments, including administration instruments, regulation instruments and economic instruments, which in general have proven important for achieving a reduction in energy intensity of GDP by 20% in the period 2005-2010. At the same time, China's contribution to international cooperative mechanisms is crucial for addressing climate change at the global level and provision of CERs under the CDM system has been the most important way of China's participation in international cooperative mechanisms to date. By the end of 2011, there had been 1773 CDM projects in China registered in the UNFCCC database and these projects are able to supply 358.89 million tonnes of CERs to industrialised countries every year. This amount represents over 70% of the overall emissions limitation and reduction commitments of industrialised countries according to the Kyoto Protocol, i.e. 491.92 million tonnes per annum compared with the 1990's level (Sun, 2011). In summary, there have been many policy instruments to cut down emissions in China, most of which can be characterised as central planning, enacting new laws and command-and-control (Cao, 2010), while the mostly frequently discussed economic instruments, i.e. taxes and emissions trading, are both in a critical stage of discussion before finally being put into place. Carbon taxes and CET schemes are both market-based instruments that aim to control CO_2 emissions in a more cost-effective way than regulations and administration instruments. Every instrument has its own advantages and problems at the same time and, more importantly, categories of instruments may be simultaneously needed to solve the challenge of climate change. Thus, it is probably important to optimise the combination of different policy instruments for a given situation.

6 Conclusions

As the largest developing country and the largest CO_2 emitter in the world, China faces a huge challenge on climate change. The main finds in this thesis were that:

- Primary energy consumption and international trade have had greater impacts on CO_2 emissions than GDP, according to mathematical calculations on time-series data for the period 1980-2008, and China's CO_2 emissions will not spontaneously decrease as GDP grows.

- Decreasing CO_2 intensity by 40%-45% of GDP by 2020 is a challenging but hopeful target

- Many policy instruments have already been introduced to cut down emissions in China, most of which can be characterised as central planning, enacting new laws and command-and-control. The main economic instruments today, i.e. carbon taxes and CET schemes, are both in the critical stages of discussion before final implementation. It is essential to have hybrid policies and to optimally combine different policy instruments for a given situation.

With the end of the first commitment period of the Kyoto Protocol approaching, a breakthrough decision was made at the Durban Climate Change Conference in late 2011 that the second commitment period under the Kyoto Protocol will begin on 1 January 2013, and emissions limitation or reduction objectives for industrialised countries in the second period were quantified. Developing countries, especially China, were also required to make more substantial commitments on limiting their emissions growth, even a binding target. The Chinese government announced at the Durban Conference that China will focus on the current mitigation target regarding CO_2 intensity by 2020 and would like to conditionally accept a worldwide legal agreement on climate change thereafter. While there is no easy way for China to go forward, there is always hope for improvement because:

'what we think, or what we know, or what we believe is, in the end, of little consequence. The only consequence is what we do'

(Ruskin, 1866).

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