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The Role of the Clean Development Mechanism in Achieving China's Goal of a Resource Efficient and Environmentally Friendly Society

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Abstract

This paper examines the impact of the clean development mechanism (CDM) on China's progress in building a resource efficient and environmentally friendly society, referred to as a dual-goal society. It presents China's CDM activities from the perspective of policy directions, administrative arrangements and capacity building as well as outlines the regional trends and distribution of CDM projects across China's 30 provinces. Based on regression analysis of 2006-2009 panel data, the research was able to provide estimates at provincial level of the impacts of CDM activities on China's CO_2 emission intensity, SO_2 emission intensity and industrial dust emission intensity.

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The study concludes that the active CDM projects are mainly located in the less developed central and west China where they have provided increased opportunities for sustainable development. Furthermore, the successful implementation of CDM projects across the country has significantly decreased the emission intensity of CO_2, SO_2 and industrial dust, which means that these activities have enhanced China's ability to build the desired dual-goal society.

Keywords: Resource efficient, Environmentally friendly, CDM, Climate change, Regression, CO_2, Estimation, SO_2

1. Introduction

With an average annual GDP growth rate of 9.8 percent[1] since the country's economic reform and opening up in 1978, China has been the world's fastest growing developing country. More recently however, the country has grabbed global attention for its ever increasing pressure on natural resources and energy demands leading to a fast deteriorating ecological environment. In 2007, China became the world's largest greenhouse gas (GHG) emitter exceeding the United States (IEA, 2010) and is continuing to be a large contributor to global warming, potentially the most serious global environmental issue (Glasby, 2002).

In response to these serious environmental concerns, the Chinese government set a lower annual economic growth target of 7% for the country's 12th Five-Year Plan period (2011-2015) with the aim to ensure a better balance between socio-economic

[1] This growth rate was estimated using data from the National Bureau of Statistics of China (www.stats.gov.cn).

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development and environmental protection. Ecological concerns and high energy demand issues have already proven to represent significant constrains on pure economic growth. For example, central China suffered a serious energy crisis in recent years which imposed power cuts on the manufacturing sector as a result of reduced hydroelectricity capacity exacerbated by a drought (Time, 2011; Reuters, 2011). Air pollution in many cities, such as Shanghai and Beijing, is attracting increasing domestic and international attention (China Daily, 2011; China Daily, 2012). The blind pursuit of economic growth without consideration of the environment will continue to trigger further exhausting of natural resources (Munier, 2006) and in the case of climate change, this can lead to irreversible negative consequences.

After realizing that the country's rapid economic growth during the 10th Five-Year Plan period (2000-2005) was achieved through extensive industrialization and urbanization at the cost of natural resources and the environment, the Chinese government wanted to see a change of course. At the fifth plenary session of the 16th Central Committee of the Communist Party of China (CPC) in 2005, it introduced and established the concept of resource efficient and environmentally friendly society, described as dual-goal society (Xinhuanet, 2005). Based on new developments in science and technology, in short this concept aims to: improve the efficiency of resource use, protect the environment and achieve maximum economic, social and ecological benefits with minimal resource consumption and environmental costs in all areas of production, construction, circulation and consumption (Jia *et al*. 2010). In order to implement the dual-goal society strategy, China is not only focussing on domestic capacity building but is also becoming a major international player,

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particularly in attracting Clean Development Mechanism (CDM) projects.

The CDM was set up by the Kyoto Protocol for the Framework Convention on Climate Change in order to help Annex I countries[2] meet their GHG emissions reduction targets in a cost-effective manner. The World Business Council for Sustainable Development described it as an initiative that offers "hope for tackling seemingly intractable problems" (WBCSD, 2010). Reducing GHG emissions in developing countries is considered to be cheaper for developed countries than doing so domestically. As the only one of the three flexible mechanisms in the Kyoto Protocol that permits developing countries to participate in global climate change mitigation efforts, CDM provides a considerable motivation for benefits to the host countries by means of environmentally friendly technology transfers (Dechezleprêtrea *et al.* 2008 and Hugé *et al.* 2010), energy efficiency and environmental improvements. For example, energy related CDM projects reduce SO_2 emissions and total suspended particulate (Vennemo *et al.* 2006; Rive, 2010) using technology developed in the West. The cement industry in China also seems to be already benefitting from CDM projects (Yan et al., 2009). Other positive examples of community use for poverty alleviation and environmental restoration have emerged in places, such as Ethiopia (Brown et al., 2011), Brazil (Perera et al., 2010), India (Boyd and Goodman, 2011; Singh, 2012), Thailand (Resanond, 2011) and Vietnam (Nguyen et al., 2011). However, there has been a general agreement that there are vast differences between developing countries in relation to their familiarity with and ability to implement such technologies (Flamos, 2010). Some argue that left to market forces alone CDM is unlikely to contribute to sustainable development (Olsen, 2007) and that the mechanism should be better aligned with the achievement of the Millennium Development Goals

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[2] Annex I under the Kyoto protocol (signed in 1997 and brought into force in 2005) includes 40 industrialized countries and countries in transition (former Eastern Block countries and Turkey which transferred in this category in 2001) as well as the European Union as a separate member. The list of Annex 1 countries includes: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxemburg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom and United States of America.

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(Bozmoski et al., 2008).

China has been the largest host country for CDM projects in the world with over 47% of the total registered projects from the United Nations Framework Convention on Climate Change (UNFCCC) and over 64% of the total annual Certified Emission Reductions (CERs) being in China (UNFCCC, 2012). The CDM mechanism seems to provide good synergies for the county's dual-goal society strategy.

Research evaluating China's progress towards a dual-goal society has already begun (e.g. Chen and Wang, 2008; Zhu and Zheng, 2010; Li and Chen, 2010), including influencing factors (Jia *et al.* 2010) and environmental regulations (Jia *et al.* 2011). However this study specifically examines the CDM impacts on the dual-goal society at a provincial level and their contribution to pollution intensity reduction.

The remainder of the paper is structured as follows. Section 2 provides a background of CDM activities in China, including review of relevant literature. The CO_2 emissions at a provincial level are estimated in section 3. Empirical analysis is conducted in section 4 to evaluate the impacts of CDM projects on China's dual-goal society. The paper ends with conclusions and relevant recommendations in section 5.

2. CDM in China

It is difficult to speculate whether the creators of the Kyoto Protocol envisaged the case for only one country to become a major recipient of CDM projects. The reality however is that China has been extremely successful in utilising this mechanism and this is attracting increasing research attention.

2.1 Background

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China's greenhouse gases (GHG) emission levels are expected to continue to increase rapidly in the near future with the growing population and rising per-capita energy consumption. However, as an Annex 1 country, China (which ratified the Kyoto Protocol on 30 August 2002) does not have any emission reduction obligation under the Kyoto Protocol. A growing number of international CDM investors consider China to be an important location for CDM projects and are willing to collaborate in enhancing its capacity to host such technologies. On the other hand, China also recognized early the potential benefits from these projects in developing potential at a national, local and enterprise level. As of 1 March 2012, there are over 3500 projects approved by the Chinese government, 1817 of which are at registered status (NDRC, 2012). The successful implementation of CDM projects in China is credited to the sound policy directives, reasonable organizational arrangements and the active capacity building at the macro and micro levels.

In order to improve the efficiency of CDM project application, three years after the ratification of the Kyoto Protocol, China developed measures for operation and management of CDM projects which provide clear institutional arrangements for project management, a good description for the required submission documents, detailed procedures for applying for a project and priority areas for CDM projects (NDRC, 2005). The overall policy environment also began to encourage improved sustainability as China's national development strategy, including promoting low carbon projects that meet the CDM eligibility criteria. For instance, the Chinese government's 11th Five-Year Plan set a target to decrease energy intensity by 20% from its 2005 level by 2010 and a target to increase the proportion of renewable energy in total national energy consumption by 2.5% from 2005 level by 2010 (National People's Congress, 2006). Further more at the UN climate change conference in Copenhagen, China stated its commitment to reducing CO_2 emissions intensity by 40-45% against the 2005 level by 2020. These national grand development strategies undoubtedly provide a strong stimulus for both local governments and businesses to increase energy efficiency, strengthen energy conservation and promote renewable energy projects. This process naturally creates a favourable policy environment for CDM projects.

Soon after the ratification of the Kyoto Protocol in 2002, the Chinese government set up the National CDM Board and reorganised the existing government apparatus such as the National Coordination Committee on Climate Change (NCCCC), originally established by China's State Council in 1990 to formulate policy responses to climate change. The National CDM Board and NCCCC together with the established CDM Service Centres in most provinces, demonstrate the strong determination of the Chinese government to facilitate CDM activities. As one of the most powerful governmental apparatus within the subsidiary bodies of China's State Council, the National Development and Reform Commission (NDRC), together with its Department of Climate Change, is a key governmental authority with a significant role in the successful implementation of CDM projects. It plays a vital part for improving energy efficiency and facilitating the transfer of environmentally friendly technology. By establishing a supportive government framework, China enhanced its domestic capacity and institutions to engage with CDM activities and further ensured the successful development of CDM projects that support its domestic sustainable development priorities (World Bank, 2010).

2.2 Previous Research

Since 2005, when the Kyoto Protocol came into effect, there has been an increasing scholarly attention on the implications CDM has on China. Part of the academic literature concentrates on the soft side of its implementation as far as policies, organisational and institutional capacities are concerned. For example, Zhang (2006) examined the major CDM capacity building projects in China and analysed the organization, regulation, institution and implementation systems of CDM projects.

Ganapati and Liu (2009) illustrated the role of China's Designated National Authority, set up to approve CDM projects, in ensuring sustainable development within the context of institutional structure, policies and CDM market. Shin (2010) came to the conclusion that China's domestic conditions have intensively influenced the effectiveness of CDM projects and that the combination of governmental intervention with weak non-governmental participation has shaped their implementation. The institutional arrangements of handling risk and barriers for project sponsors in the CDM practice in China were reviewed by Teng and Zhang (2010). Their analysis suggested that a clear institutional setting and implementation strategy are crucial for the effective implementation. They also pointed out that the geographically uneven distribution of CDM projects is partly triggered by the uneven capacity building practices and lack of proper methodology.

Technology transfer has been another area of scholarly interest. For instance, Dechezleprêtrea *et al.* (2009) examined international technology transfer of CDM projects comparing China with Brazil, India and Mexico and concluded that the proportion of China's CDM projects including international transfer of technology is 59% which was higher than in the case of India (12%) and Brazil (40%) but lower than Mexico (68%). Further more, Wang (2010) examined factors that have influenced technology transfer through CDM projects in China and his empirical results indicate that the adoption of foreign technologies is largely influenced by the proportion of total income derived from the CERs. However the incompatibility of the Chinese hospitable regulation and institutional system with the much slower CDM validation and registration process delayed the realisation of these CER benefits.

There have been several studies evaluating the impact of CDM projects on China's environmental performance, namely gaseous emissions such as CO_2, SO_2, NO_x and pollution with total suspended particulate. Vennemo *et al.* (2006) analysed the domestic environmental and health benefits from China's energy related CDM

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potential and showed that it will reduce SO_2 emissions by 2.5%-15% and will create an additional monetary benefit of 1.45 billion RMB per year. Rive and Rübbelke (2010) examined the transfer of CDM funds from the EU to China using SO_2 reduction as the primary indicator for China's environmental protection and concluded that a higher CDM subsidy rate has increasing poverty-alleviating benefits. Further research by Rive and Aunan (2010) estimated the SO_2, $PM_{2.5}$, and NO_x co-benefit rates of 11 CDM project types for seven regions in China. Their results indicate that the CDM projects are likely to make a notable contribution to SO_2 reductions and the monetized health and agricultural benefits from reduced PM and NO_x amount to roughly 12 billion RMB per year, approximately one-third of the market value of the associated CERs. More recently, Maraseni and Gao (2011) tested the advantages of a unilateral CDM in reducing risks to the host country investors, lowering the transaction costs and keeping rent in the host country, using a questionnaire survey in China, which dominates the world CDM market.

Despite the increasing popularity of CDM activities and intensifying academic interest in them, critics argue that the mechanism puts an overt emphasis on the CDM market rather than focusing on sustainable development per se (Pearson, 2006; Sutter and Parreño, 2007). In particular, to date there has not been a study that links CDM projects with sustainability of China's provinces in the context of the dual-goal society. This is the main focus of this paper.

2.3 Trends and Distribution of CDM Projects in China

After 6 years of development of the CDM market, China has become the largest host country in the world. Fig. 1 shows the trend of active CDM projects in China, approved by the Chinese Government as of 1 March 2012. In 2005, the CDM market was rather sluggish with only 3 projects approved as of the end of the year. However in 2006, the market rose quickly with 237 new CDM projects added. The growth rate

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continued to accelerate in the following year, with the number of projects approved in the third quarter of 2007 being even higher than the total in 2006. There are several factors contributing for China's success in attracting CDM projects. Firstly, the country was able to establish a sound government system with reasonably good organizational arrangements that facilitate the establishment and accreditation of the projects (Hong et al., 2011). Secondly, China's recent economic development has created a wide-ranging array of skills which allow for technology transfer, technology learning and adaptation at the macro and micro level. Thirdly, the overall business environment of the country is encouraging new investments which fuel further economic growth. Fourthly and probably most importantly from a CDM point of view, China's economy needs to be decarbonized and this mechanism contributes towards the much needed reduction in GHG emissions.

The uncertainty regarding the post-Kyoto era and the global financial crisis cooled down the CDM market in more recent years, but the steady development trend remains. The numbers of active CDM projects in China indicate that the country's market is developing smoothly and will be a positive contributor to the dual-goal society strategy.

Table 1 provides a comparison in CDM project location and relevant CERs for the eastern, central and western regions of China. The three areas of new and renewable energy, energy efficiency improvement and methane to market are dominating the Chinese CDM projects, representing over 94% of the total number and 76% of total CERs. The new and renewable energy projects category alone accounts for over 73% of the projects and over 53% of the CERs. Furthermore, the area of HFC-23 decomposition, which has only 11 projects in total distributed mostly in the eastern regions of the country, represents over 11% of the total volume of CERs and is ranked third (after new and renewable energy and energy efficiency) amongst all types of CDM projects. West China, which is the less economically developed part of the

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country, has attracted the largest number of CDM projects, namely 49% of the total. These projects on average seem to be smaller as the CERs of west China are approximately equal to those of east China, which accounts for 40% of the total number of projects.

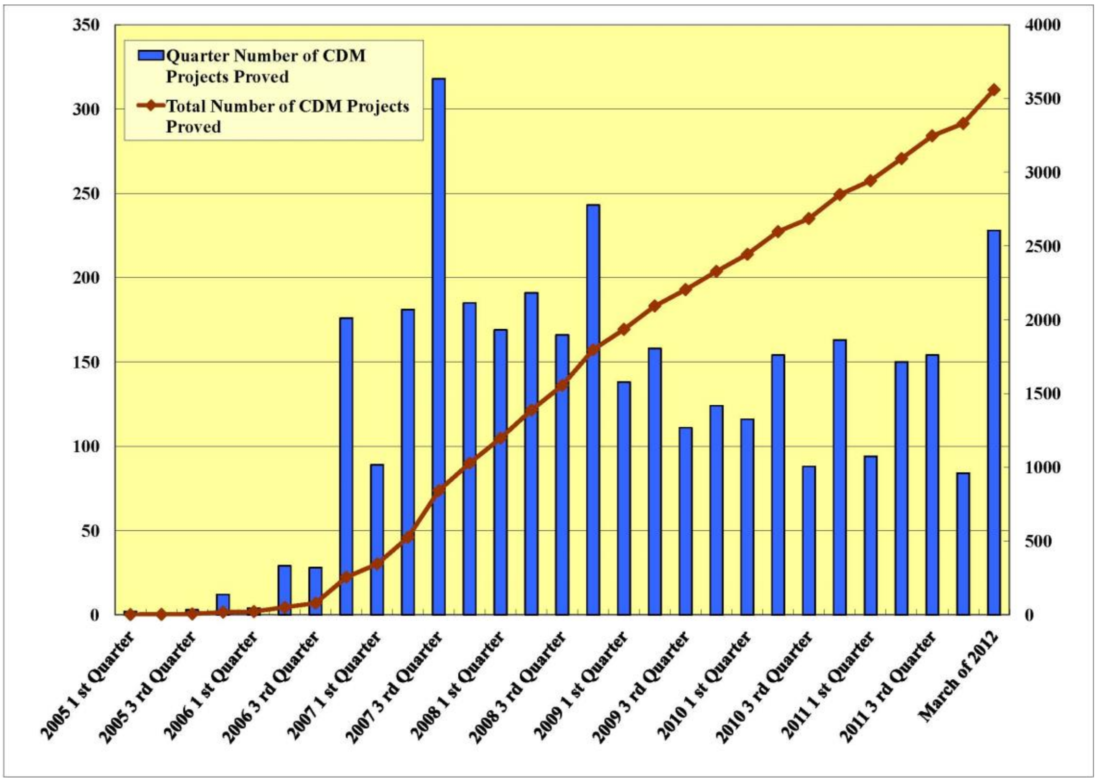

Fig. 1. Trends of Active CDM Projects in China as of 1 March 2012

Source: NDRC (2012).

Table 1 Number of Active CDM Projects and CERs (ktCO_2) in China (as of 1 March 2012)

Project Type	East China		Central China		West China		Total	
	Projects	CERs	Projects	CERs	Projects	CERs	Projects	CERs
New and Renewable Energy	588	63351	472	51825	1487	199523	2547	314699

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Energy Efficiency	200	32213	217	32945	105	11722	522	76880
Methane to Markets	63	10019	130	42242	59	12079	252	64340
Alternative Fuel	26	21733	15	2978	6	765	47	25476
Garbage Burning Power	26	7084	3	383	16	4737	45	12204
N_2O Reduction	8	12081	8	9094	12	4134	28	25308
HFC-23 Decomposition	10	64733	/	/	1	2066	11	66798
Forestry	1	1	/	/	3	116	4	117
Others	25	3408	13	1540	13	3087	51	8035
Total All Types	947	215000	858	141000	1702	238229	3507	593858

Source: NDRC (2012).

The rapid development of the CDM market in China has led to increasing concern about the distribution of CDM projects, including barriers to an equitable distribution across countries, sectors and regions (Ellis and Kamel, 2007). A similar uneven geographical distribution of active CDM projects is also witnessed in China across different provinces (see Fig. 2). As at March 2012, over 27% of the approved projects concentrated in 3 provinces: 361 in Yunan, 328 in Sichuan and 288 in Inner Mongolia, all located in west China and possessing rich hydropower and wind power resources. At the other end of the spectrum, the 3 municipalities of Beijing, Shanghai and Tianjin, along with Tibet (where the circumstances are vastly different), are ranked the last four of all China's provinces. These municipalities have well developed infrastructure and leading technologies and are not as suited to host CDM project, as the mechanism aims to encourage mutually beneficial technology transfer opportunities for poorer regions (Amin and Marinova, 2009). The central and western regions of China whose economies are less developed have attracted about 73% of all projects and 64% of the total volume of CERs, thus reflecting a successful implementation of the CDM aimed at enhancing the sustainability of the hosting country.

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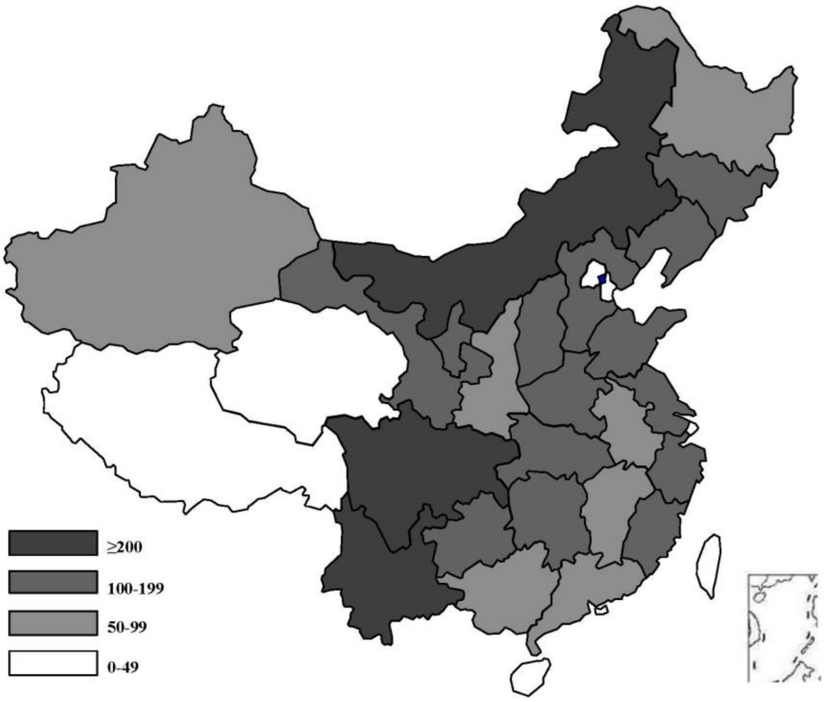

Fig. 2. The Geographical Distribution of Active CDM Projects in China

(as of 1 March 2012)

Source: Compiled from NDRC (2012)

3. Estimation of Provincial CO_2 Emissions

This study aims to examine the impacts of CDM projects on China's sustainable development using regression analysis of panel data. We estimate the influences of CDM projects on China's provincial CO_2 emission intensity, SO_2 emission intensity and industrial dust emission intensity for the period of 2006-2009. The data of SO_2 and industrial dust emissions and the Gross Regional Product (GRP) for China's provinces are available from *China Environment Statistical Yearbook* (National Bureau of Statistics of China, 2007-2010) and *China Statistical Yearbook* (National Bureau of Statistics of China, 2010), hence we can directly calculate the SO_2 emission intensity and industrial dust emission intensity. However, China's statistical publications do not contain data on a provincial level for CO_2 emissions; national

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estimates for China are available from some international organizations, such as the International Energy Agency (IEA) and U. S. Energy Information Administration (EIA). Therefore, we firstly estimate the CO_2 emissions for the provinces of China, following the method proposed by the Intergovernmental Panel on Climate Change (IPCC, 1996). The calculation formula for the provincial CO_2 emission intensity is shown in equation (1).

$$CEI_{it} = \frac{CO_{2it}}{GRP_{it}} = \frac{\sum_{k=1}^{n} EC_{kit} \times EF_K}{GRP_{it}} \tag{1}$$

where CEI_{it} represents the CO_2 emission intensity of the ith province in year t, CO_{2it} is the amount of the ith province's CO_2 emission in year t, GRP_{it} indicates the gross regional product of the ith province in year t, EC_{kit} is the kth category of energy consumption in the ith province in year t and EF_k is the emission factor of the kth category of energy.

Using the provincial energy balance sheets from *China Energy Statistical Yearbook* (National Bureau of Statistics of China, 2007-2010), we can calculate the kth category of energy consumption by summing the energy used for thermal power and heating supply, the energy loss and the total final energy consumption eliminating the non-energy use of this category of energy. The emission factor can be calculated according to the *Emission Factor Database* (IPCC 2006). Our estimation results show the total sum of CO_2 emissions for all Chinese provinces in 2009 to be 7.75 trillion tons. This is similar to the EIA data, namely 7.71 trillion tons (EIA, 2010), thus indicating that our estimation is reliable. Table 2 presents the estimation results for China's provincial CO_2 emission intensities and annual decrease rates.

Table 2 China's Provincial CO_2 Emission Intensities and Annual Decrease Rates

Regions	2006 kg/yuan	2007 kg/yuan	2008 kg/yuan	2009 kg/yuan	Annual decrease rate (%)

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East China	Beijing	0.1128	0.0987	0.0859	0.0793	11.08
	Tianjin	0.2264	0.2074	0.1693	0.1638	10.22
	Hebei	0.4392	0.3931	0.3529	0.3374	8.41
	Liaoning	0.3191	0.3061	0.2568	0.2481	8.05
	Shanghai	0.1485	0.1329	0.1219	0.1148	8.23
	Jiangsu	0.2017	0.1810	0.1593	0.1469	10.04
	Zhejiang	0.1797	0.1699	0.1509	0.1431	7.32
	Fujian	0.1828	0.1708	0.1541	0.1530	5.75
	Shandong	0.2799	0.2647	0.2379	0.2204	7.65
	Guangdong	0.1331	0.1224	0.1086	0.1054	7.48
	Hainan	0.1705	0.1595	0.1546	0.1517	3.81
	Mean	0.2176	0.2006	0.1775	0.1695	8.00
Central China	Shanxi	0.6792	0.6033	0.5362	0.5422	7.23
	Jilin	0.4143	0.3573	0.2952	0.2653	13.81
	Heilongjiang	0.2906	0.2791	0.2511	0.2448	5.56
	Anhui	0.3100	0.2848	0.2672	0.2612	5.55
	Jiangxi	0.2099	0.1931	0.1660	0.1550	9.62
	Henan	0.3340	0.3020	0.2534	0.2390	10.56
	Hubei	0.2991	0.2715	0.2247	0.2116	10.89
	Hunan	0.2805	0.2442	0.1995	0.1836	13.18
	Mean	0.3522	0.3169	0.2742	0.2628	9.30
West China	Inner Mongolia	0.6489	0.5800	0.5311	0.4990	8.38
	Guangxi	0.2231	0.2088	0.1700	0.1705	8.57
	Chongqing	0.2363	0.2149	0.2192	0.2042	4.75
	Sichuan	0.2388	0.2137	0.2009	0.2002	5.71
	Guizhou	0.8253	0.6777	0.5190	0.5288	13.79
	Yunnan	0.4005	0.3610	0.3003	0.3090	8.28
	Shaanxi	0.2988	0.2691	0.2409	0.2413	6.87

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	Gansu	0.4129	0.3825	0.3491	0.3145	8.67
	Qinghai	0.4033	0.3499	0.3305	0.3209	7.34
	Ningxia	0.9508	0.8082	0.7063	0.6409	12.32
	Xinjiang	0.3875	0.3652	0.3386	0.3816	0.51
	Mean	0.4569	0.4028	0.3551	0.3464	8.81
Mean for China		0.3413	0.3058	0.2684	0.2593	8.75

Source: author's calculation.

The strategy of building a dual-goal society has put regional development in China in a completely new trajectory, one that values a more balanced approach to the dominant economic focus (including improving resource efficiency by increasing energy efficiency and reducing exhaust emissions). This is also consistent with developing a low carbon economy in the country and many indicators point in this direction. Between 2006 and 2009, provincial CO_2 emission intensities decreased significantly with an average annual decrease rate of 8.75% (see Table 2), which was also above the 11th Five-Year Plan's carbon reduction target. The CO_2 emission intensity levels were lower for China's eastern regions than those for its central and western regions. The latter however had overall higher mean annual decrease rates with Jilin (in central China) and Guizhou (in West China) having the highest annual decrease rate in CO_2 emission intensities, 13.81% and 13.79% separately. This shows that the regional imbalance is gradually reducing as China is gradually adopting the low carbon economy.

Fig. 3 compares the CO_2 emission intensities of China's provinces in 2006 and 2009. They have decreased across all provinces, be it to a different degree, but overall the CO_2 emission intensities in China's western regions are much higher than those of central China and even higher than those of east China. The two provinces with the highest CO_2 emission intensity are Ningxia and Guizhou in west China and the

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provinces with the lowest intensities are Beijing Municipality and Guangdong Province located in the eastern regions. The distribution of China's CO_2 emission intensities demonstrates a serious regional imbalance with the mean of west China being more than twice that of east China, which indicates that the western regions with poor economic development and less technical capability have worse capacity to develop a low carbon economy.

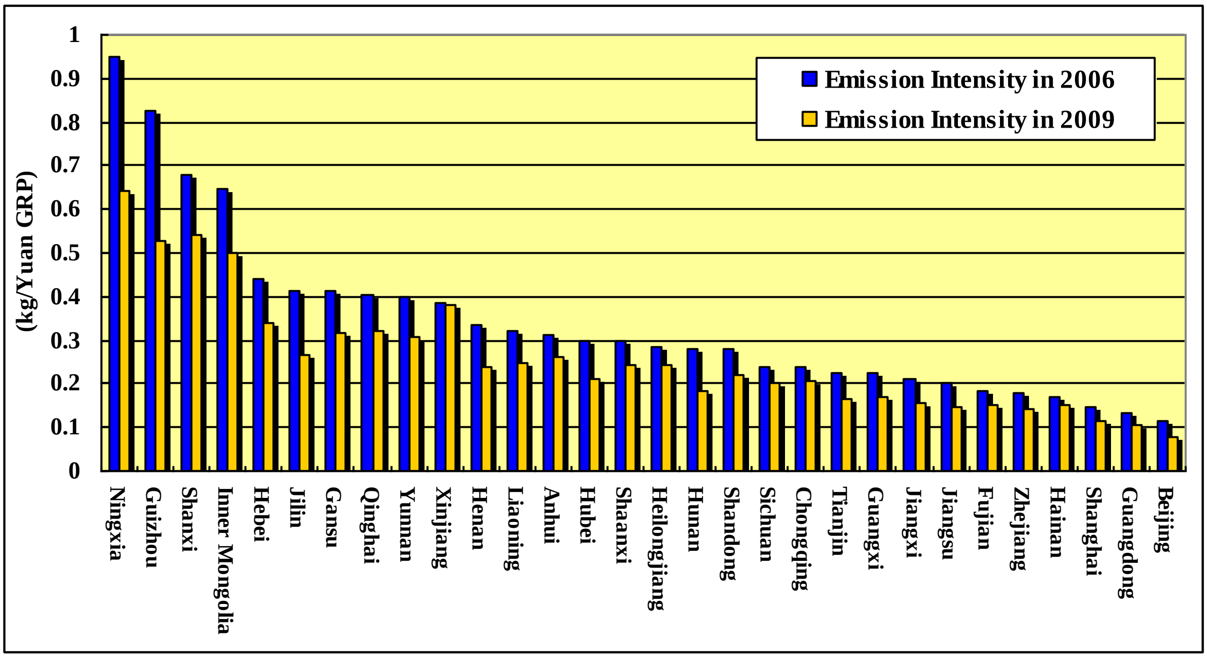

Fig. 3. The CO_2 Emission Intensities of China's Provinces in 2006 and 2009.

Source: authors' calculation.

4. Impacts of CDM Projects on the Dual-goal Society Strategy

Using 2006–2009 panel data for 30 administrative regions, we further conduct a simple regression equation in logarithmic form to evaluate the influence of CDM activities on China's provincial CO_2 emission intensity, SO_2 emission intensity and industrial dust emission intensity, which represent the main targets in the dual-goal society strategy.

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4.1 Empirical Model and Evaluation

Three simple logarithmic regression equations (2 to 4) are used to conduct the model estimation for the respective emissions. The logarithmic form of the equations allows heteroscedastic data to be avoided and improves the accuracy of the model estimation. The basic models are as follows:

Model for CO_2:

$$\ln CEI_{it} = \beta_0 + \beta_1 \ln CDM_{it} + \mu_{it} \quad (2)$$

where CDM_{it} represents the number of proved CDM projects for the *i*th province by the end of year *t* and μ_{it} is the random error.

Model for SO_2:

$$\ln SEI_{it} = \beta_0 + \beta_1 \ln CDM_{it} + \mu_{it} \quad (3)$$

where SEI_{it} indicates the SO_2 emission intensity of the *i*th province in year *t* and μ_{it} is the random error.

Model for industrial dust:

$$\ln IEI_{it} = \beta_0 + \beta_1 \ln CDM_{it} + \mu_{it} \quad (4)$$

where PEI_{it} indicates the industrial dust emission intensity of the *i*th province in year *t* and μ_{it} is the random error.

The estimation results obtained with Eviews6.0 with ordinary least squares (OLS), are shown in Table 3. The values of the Hausman statistics suggest that the fixed effect model should be accepted as the final model for all of the three models.

Table 3 Regression Results of the Impacts of CDM Activities on China's CO_2, SO_2 and industrial dust emissions

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Independent Variable	Model for CO_2		Model for SO_2		Model for industrial dust	
	Fixed effect	Random effect	Fixed effect	Random effect	Fixed effect	Random effect
ln（*CDM*）	-0.0869 ***	-0.0854	-0.2211 ***	-0.2194 ***	-0.3336 ***	-0.3290 ***
	(0.0092)	(0.0092)	(0.0115)	(0.0115)	(0.0210)	(0.0209)
Adjusted R-squared	0.9628	0.4071	0.9775	0.7421	0.9669	0.6559
Observations	120	120	120	120	120	120
Hausman Test (Chi-Sq. Statistic)		5.9658 **		7.6743 ***		11.2027 ***

Note：*, ** and ***represent significance at 10%, 5% and 1% levels, respectively.

Source: authors' calculation.

4.2 Analysis of the Evaluation Results

(1) The CDM projects have improved the performance of China's provinces in relation to carbon emission reduction. The regression results in this study (namely a statistically significant regression coefficient of -0.0869 at 1% level) show that the increase in the number of approved CDM projects has significantly decreased China's provincial CO_2 emission intensities. With the primary goal of GHG emissions mitigation, the CDM is considered by many as a key means to boost environmentally friendly technology transfer and diffusion which can improve the energy efficiency and enhance the capacity for sustainable development in host countries.

However, academically there is still no general agreement as to how beneficial CDM is. Some optimists applause its positive role of CDM and provide estimates for the volume of GHG reduction. For instance, Vennemo *et al*. (2006) suggest that the estimated CDM potential of China can reach up to 236 Mt CO_2 per year in the period from 2008 to 2012 while Rive and Aunan (2010) demonstrate that the CERs via

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China's CDM activities in 2010 will be approximately 300 $MtCO_2$. On the other hand, environmental critics argue that CDM has not been effective in reducing GHG emissions, slowing global warming or achieving sustainable development in developing countries (Shin, 2010).

The results of this study show that CDM has had a very positive impact on China. The sound policy directives, appropriate institutional arrangements and positive capacity building activities have allowed for the CDM projects to be successfully implemented in China's provinces and this has accelerated the transition to a dual-goal society.

(2) The CDM activities have also played a significant role in reducing SO_2 emissions. The regression results show that the respective coefficient for CDM projects is -0.2211 and passes the significance test at 1% level, which indicates that the CDM activities can significantly improve China's provincial SO_2 emission abatement. The rapid industrialization of the country has caused substantial damage to its environment, including widespread acid rain arising from the SO_2 emissions. As coal forms up to 70% of China's energy consumption in recent years, the coal-related SO_2 emissions combined with CO_2 cannot be ignored. The study by Vennemo *et al.* (2006) shows that the SO_2/CO_2 ratio is distributed in the range of 8.7 to 10.8 kg SO_2/ton CO_2. Furthermore, according to Rive and Aunan (2010), the estimated actual SO_2 reduction achieved in China is 2132 kiloton from 2006 to 2010 and our analysis confirms the reliability of their findings. The successful implementation of CDM projects has made remarkable contribution on SO_2 emission reduction - one of the main emission reduction objectives of the environmentally friendly dimension of China's dual-goal society.

(3) Furthermore, the CDM activities have had a considerably influenced on industrial dust emission. According to the regression results (see Table 3), the statistically significant at 1% level regression coefficient of -0.0869 suggests that the CDM

projects have reduced the industrial dust emission intensity in China's provinces. As one of the main air pollutants, the respirable suspended particulate derived from industrial dust can cause health loss and harm the human respiratory system. As pointed out by Wei et al. (2009), the external costs associated with industrial PM_{10} amounted to 475 billion yuan in China's 30 provincial capitals. The air pollution associated with industrial dust emission has become a serious consideration for China's public health, drawing a lot of attention from the public and the government and becoming an important aspect of China's dual-goal society. In this study, our regression analysis indicates that the CDM activities have also boosted China's dual-goal society strategy by reducing its provincial industrial dust emission intensities.

5. Conclusion and Recommendations

This study analyzed the CDM activities in China within the context of the country's dual-goal society strategy. The analysis conducted allowed to evaluate the impacts of CDM projects on China's provincial CO_2, SO_2 and industrial dust emission intensities. The main conclusion from the study is that the mechanism has been extremely beneficial as outlined below:

• After seven years' of CDM activities, China has established a dominant position in the global CDM market which can be attributed to its sound policy directives, good institutional arrangements and supportive capacity building activities. Many argue that China's poor regions should be given priority for economic growth (Xue et al., 2011). In fact, the poorer western regions that are still in need of development opportunities have attracted nearly half of China's CDM projects. The regional distribution of the CDM projects helps abate to some extent the regional imbalance of development.

• The estimation results for provincial CO_2 emissions indicate that China has achieved remarkable improvement in its performance in carbon emission reduction with an average annual decrease rate of 8.75% in the CO_2 emission intensity (higher that the targets of the 11th Five-Year Plan). However, regional imbalance still exists with the mean of CO_2 emission intensity in west China being more than twice higher that in east China. Therefore, transforming west China towards a low carbon economy through economic adjustment and beneficial transfer of appropriate technologies is vital for China's dual-goal society strategy.

• The CDM activities have significantly reduced China's provincial emission intensities of CO_2, SO_2 and industrial dusts, all of which being important aspects of the dual-goal society concept. The continuing effective implementation of CDM projects in China will facilitate the country's smooth transformation towards a resource efficient and environmentally friendly society. The government seems committed to this process and the CDM market.

As the first commitment period draws to a close, there are many questions asked about the post-2012 future of the Kyoto Protocol, including the Clean Development

Mechanism. The research evidence from this study as well as from other sources (e.g. UNFCCC, 2011) confirms that CDM projects are starting to make their contribution towards sustainable development. It is already clear that CDM will continue in the future with a second commitment period confirmed for 2013-2017 (UNFCC, 2012). However emissions targets are still being negotiated and a long list of potentially complex and/or controversial surrounding issues, such as nuclear power (Perera et al., 2010) or carbon capture and storage (Carbon Capture Journal, 2011), remains. So far China has proven that CDM is not just a myth but a reality (Cox, 2010) and a powerful way to deliver substantial changes in areas where they are most needed. The new agreement should be able to allow China to build on these achievements and continue its pursuit of the new dual-goal society.

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