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Impacts of carbon trading scheme on air pollutant emissions in Guangdong Province of China

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ABSTRACT

This study aims to assess the impacts of carbon emission trading scheme (ETS) policy on air pollutant emission reduction in Guangdong (GD) Province, especially with respect to the embedded air pollutant emission flow caused by carbon ETS. A Computable General Equilibrium (CGE) model is constructed to project the local emission trajectory of CO_2 and air pollutants under business as-usual (BaU) and policy scenarios in GD province and the rest of China from 2007 to 2020. To achieve the energy and carbon intensity targets, the carbon constraint and ETS policy are employed to promote energy saving and CO_2 emission reduction. The simulation results show that the carbon ETS has the co-benefits of reducing SO_2 and NO_x emissions by 12.4% and 11.7% in 2020 compared with the BaU scenario. Along with the carbon trading volume of 633 million tons created by the ETS scenario, an embedded amount of 38,000 tons of air pollutants is exchanged among carbon trading sectors, which valued about 50 million USD. Although the current carbon and air pollutant emission markets are independent from each other, the evaluation of the co-benefits needs to be considered further in the policy making process.

Introduction

As a result of the rapid development of China's economy, energy consumption increases drastically and various harmful substances from energy consumption are discharged to the atmospheric environment causing serious air pollution. Especially, due to China's coal dominated energy structure, acid rain and smog have seriously polluted the environment. Furthermore, as the ownership of China's automobile has greatly increased in recent years, nitrogen oxide (NO_x) and particle matter (PM) have become the main air pollutants in an urban area, causing adverse effects on the health of urban residents.

Although during the "11th five-year" (FYP during 2006–2010) period the energy intensity in GD decreased by 16.4%, the conventional growth mode of industrialization and urbanization results in rising energy demand and CO_2 emission as well as environmental degradation. As one of the most important economic provinces of China, Guangdong (GD) consumes 4.6% of China's coal, 21.9% of crude oil, 12.8% of natural gas and 10.6% of electricity in 2012 (Table 1). Consequently, air pollution in Guangdong and the Pearl River District has deteriorated in recent years.

In order to prevent further deterioration of air quality and protect human health and the ecosystem, the Chinese government has implemented a series of national control policies to reduce the emissions of air pollutants since 2005 (Wang and Hao, 2012). The 11th FYP for national environmental protection required the reduction of annual emissions of sulfur dioxide (SO_2) in 2010 by 10% from its 2005 level. Furthermore, in China's 12th FYP (2011–2015), nationwide controls of NO_x emission will be implemented along with the controls of SO_2 and primary particles. The Ministry of Environmental Protection (MEP) of China has set a target to reduce the national NO_x emissions in 2015 by 10% from the 2010 level.

At the regional level, the Guangdong provincial government has promulgated a serial policy in thermal power plant nitrogen, volatile organics, motor vehicle pollutant emission, industrial boiler pollution and cement industry, which all emphasizes on establishing the work progress report, supervising the notification mechanism, and strengthening the monitoring capacity-building (People's Government of Guangdong Province, no. 6, 2014). Furthermore, Guangdong Province also introduced a "comprehensive energy saving and reduction program" to achieve the main target of energy saving and air pollutant by 2015, which requires the energy consumption of per GDP to decrease by 18% and 31% in 2010 and 2005, respectively; chemical oxygen demand (COD) and sulfur dioxide (SO_2) emissions

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to reduce by 12% and 14.8% compared with 2010, respectively; and ammonia and nitrogen oxide (NH_3 and NO_x) emissions to decrease by 13.3% and 16.9% in 2010, respectively (People's Government of Guangdong Province, no. 14, 2012). Guangdong was also selected as a low-carbon pilot province designated as one of the 13 pilot low-carbon zones in China by the National Development and Reform Commission (NDRC) in 2010, with a tough target of reducing carbon intensity of GDP by 19.5% and at least 45% from 2005 level in 2015 and 2020, respectively. In addition, some pilot energy and climate polices at the regional level are implemented and assessing such policies with complex system models have attracted attention in China. For instance, Guangdong has been selected as a pilot to conduct the carbon emission trading scheme (ETS) in 2013, and the air pollutant trading market has started in 2014 in this province. Evaluation of the effectiveness of carbon mitigation policies is vital for future policy design at both national and regional levels.

Table 2
Common socio-economic assumptions shared by all scenarios.

	2007–2010	2011–2015	2016–2020
Guangdong			
Expected GDP growth rate	10.8%	8.0%	7.5%
TFP improvement	5%	4%	3.5%
Population growth rate	3%	0.64%	0.47%
Energy efficiency improvement	4% for solid fuel; 2% for liquid fuel; 2% for gas fuel; 8% for electricity		
Air pollutant abatement rate	25% for SO_2; 0% for NO_x		50% for SO_2; 20% for NO_x
Rest of China			
Expected GDP growth rate	10.0%	8.0%	7.5%
TFP improvement	5%	5%	5%
Population growth rate	0.63%	0.62%	0.54%
Energy efficiency improvement	5% for solid fuel; 5% for liquid fuel; 2% for gas fuel; 4% for electricity		

Literature review

So far there is a growing awareness that sustainable development requires an integrated and system-level redesign of the entire socio-ecological regime to coordinate different management policies. Some researchers discussed the concept of co-benefits in the air pollution control and counter climate change (Kanad et al., 2013; Nemet et al., 2010; Jack and Kinney, 2010). If well established, the evaluation of such dual or multiple benefits or profit schemes could provide strong incentives for the adoption of air pollutant control protection measures and CO_2 emission reduction actions which will help to construct a whole reduction market financed by different stakeholders. Several previous studies have already analyzed the implications of climate and energy saving policies on air pollutants in developed and developing countries (e.g. Hasanbeigi et al., 2013; Williams et al., 2012; Bollen et al., 2009). A range of studies have focused on the co-benefits of carbon mitigation measures induced air pollutant reduction in China (Aunan et al., 2004; Jiang et al., 2013; Dong et al., 2015), co-benefits of energy saving entail reductions in air pollution and the improvement of public health (Chen et al., 2007), environmental benefits of various vehicles by employing a case study in Shenyang, China (Geng et al., 2013), and co-benefits of energy and carbon mitigation policies on air pollutant reduction (Mao et al., 2012; Xi et al., 2013; He et al., 2010). For example, Aunan et al. (2004) found that the implementation of carbon-abating options could lead to reduction of SO_2 and particles. And the paper argued that the co-benefits need to expand the practical scope for Greenhouse Gas (GHG) mitigation measures under the clean development mechanism (CDM). Chen et al. (2007) found that the energy saving policies can entail reductions in air pollution and the improvement of public heath as a co-benefit. Geng et al. (2013) analyzed the cost effectiveness and environmental benefits of various vehicles by employing a case study in Shenyang, China. Mao et al. (2012) used the CIMS model to predict the air pollutant reduction under the constraint of CO_2 emission intensity of the Chinese transportation, and compared the air pollutant reduction in carbon tax and fuel tax policy. And by combining a top-down type Computable General Equilibrium (CGE) model and bottom-up type GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies)-China model, Dong et al. (2015) analyzed the co-benefit of mitigating carbon emissions on air pollution in 30 provinces of China.

In general, these studies show that climate policy implementation has co-benefits on air pollutant reduction and decreases the risk of political opposition.

However, as Williams et al. (2012) argued, the previous studies demonstrated the increasing prevalence and importance of integrating co-benefits into impact studies conducted in developing countries such as China. Nevertheless, data limitations and a lack of resources and experience with large-scale general equilibrium (such as CGE) or bottom-up models and sophisticated air quality models can present significant barriers to assess the economic co-benefits. In addition, these aforementioned studies have widely conducted policy analyses on national or sectoral in China and around the world.

As defined by the general equilibrium theory of Walras, the economy composed with supply and demand is equalized across all of the interconnected markets in the economy, such as in energy products and carbon emission mitigation policy. Further, the abstract general equilibrium structure formalized by Arrow and Debreu is combined with realistic economic data to solve numerically for the levels of supply, demand and price that support equilibrium across a specified set of markets, which is called the Computable General Equilibrium (CGE) model (Sue Wing, 2006). So, CGE models are widely used in analyzing and estimating the impacts of policies such as taxes, subsidies, quotas or transfer instruments on the economy and other

Table 1
Selected indicators of Guangdong Province in 2012.
Source: energy data from NBS (2013), economic data from GDBS (2013), population from NBS (2013) and the authors' calculation.

	Value	Share in China
Population (million persons)	105.9	7.8%
Primary energy (million ton coal equivalent)[a]		
Coal	117.3	4.6%
Crude oil	64.5	21.9%
Gas	15.2	12.8%
Electricity	43.8	10.6%
Economic indicators (billion 2012 US dollar (USD))		
GDP	907.9	11.0%

[a] The value of conversion factor is (1 kgCE = 29,306 kJ) and (1 kWh = 0.1229 kgCE).

Table 3
Key carbon policy assumptions — all scenarios.

Scenario	Renewable energy	Emission trading	Emission constraint
BaU	Low level	None	No carbon cap.
BaU_RE	High level	None	No carbon cap.
SAV	High level	None	Carbon intensity reduces 45% over 2005–2020; annual growth rate of carbon between 2013 and 15: power sector 0.3%, oil refinery 2%, cement 1%, iron and steel 6%; 2016–20: power sector 0.1%, oil refinery 2%, cement 1%, iron and steel 5%.
SAVET	High level	Yes	